# THE EFFECTS OF QUADRICEPS KINESIO TAPE™ ON GAIT

# IN INDIVIDUALS WITH KNEE PAIN

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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BY

Jingyu Hu

Thesis Committee:

Kaori Tamura
Bret Freemyer
Yukiya Oba

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## Abstract

**Purpose:** To determine the effect of Kinesio Tape™ on pain and gait for people with symptomatic knee pain, when applied the Kinesio Tape™ on the quadriceps muscles.

**Methods:** 22 participants with knee pain were randomly assigned to sham or the Kinesio Tape™ (KT) group, while 11 participants without knee pain was assigned to a control group. The control and the KT groups received the quadriceps facilitation tape method, while participants in the sham group had sham KT (without tension) application. There were four data collections: baseline, immediate post-tape, three days post-tape, and three days post-tape removal. Six walking trails were collected via 3D motion capture system. The Knee Injury and Osteoarthritis Outcome Score (KOOS) was used to assess knee pain and function. The gait variables analized were walking velocity, peak knee adduction angle (PKAA), peak knee adduction moment (PKAM), peak knee flexion angle (PKFA), KFA at initial contact (IC), peak knee flexion moment (PKFM), maximum vertical ground vertical force (GRF), and loading rate.

**Result:** There were group effects for all KOOS parameters ($p < 0.001$) indicating the higher knee pain level and lower functionality in knee pain (KT and sham) groups, while there were time effects for walking velocity ($p = 0.002$) indicating learning effect for all groups. Additionally, PKAA ($p = 0.004$), PKFA ($p = 0.027$) were significantly different in the KT group; however, clinical significance remains unclear on these variables.

**Conclusion:** Kinesio Tape™ has effects on the gait variables for individuals with knee pain, particularly for PKAA and PKFA, but it is unclear whether the effects are positive or not.

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## List of Abbreviations

| Abbreviations | Names |
|---|---|
| KT | Kinesio Tape™ |
| KOOS | Knee Injury and Osteoarthritis Outcome Score |
| PKAA | Peak Knee Adduction Angle |
| PKAM | Peak External Adduction Moment |
| PKFA | Peak Knee Flexion Angle |
| KFA at IC | Knee Flexion Angle at Initial Contact |
| PKFM | Peak External Flexion Moment |
| GRF | Ground Reaction Force |
| OA | Osteoarthritis |
| ADLs | Activities of Daily Living |

# CHAPTER 1. INTRODUCTION

Osteoarthritis (OA) is a metabolic and slowly developing disease in older adults, which makes patients experience restricted activities, decreases their ability to do activities of daily living (ADLs), and do fewer physical exercise in their age group.[1] In OA, the knee is the most commonly affected joint causing walking-related disability and clinical symptoms for the elderly.[2] Knee OA leads to knee disability in an estimated 10% of people 50 years of age and older, 20% of whom are severely disabled.[3] Among knee OA manifestations, pain is the most significant concern, which is highly associated with quadriceps femoris muscle weakness.[4] Functional impairment in knee OA patients, such as instability and physical disabilities, is also common concerns, which are related to pain, quadriceps femoris weakness, and age.[5]

Quadriceps femoris muscle weakness is a common deficit among knee OA patients. Previous studies focused on the strength of the quadriceps femoris, and they found that both isometric and isotonic quadriceps femoris strength was weak.[6,7,8,9] The quadriceps femoris muscle plays a vital role in walking, standing, and stair negotiation. However, when performing these ADLs, knee OA patients avoid activating quadriceps femoris.[10] Patients minimized the use of quadriceps femoris of the painful knee due to pain, which could partially contribute to muscle disuse atrophy[11]. Therefore, the quadriceps femoris muscle weakness is closely associated with pathologic development, as well as the abnormal gait patterns of knee OA.[12]

Previous biomechanics studies showed that the knee OA affected gait patterns compared with matched control, such as reduction in walking velocity and cadence, larger double support time, and smaller stride length.[12, 13, 14,15] The incidence of knee OA is related to age and the degeneration of cartilages, which are at least cause harmful joint loading.[16, 17] Thus, knee OA patients show decreased loading rate of vertical ground reaction force (GRF), lower external knee flexion moment (KFM) in mid-stance, higher external knee adduction

moment (KAM), and reduced knee external extension moment in the late stance phase[12, 15, 18, 19] The reduction in ground reaction force is also attributed to the slower walking velocity. The slower walking velocity increases the loading rate, thereby causing lower GRF.[11] In addition, the gait of knee OA patients change due to the various levels of severity.[20] Walking velocity decreases incrementally from asymptomatic individuals to severe knee OA patients.[12] Individuals with symptomatic knee pain and moderate knee OA patients have milder symptoms, especially less pain, compared with severe knee OA patients. Thus, slower walking is related to knee pain.[21] Decreased knee ROM is associated with pain and joint dysfunction. Therefore, decreased knee ROM becomes more apparent with pathologic development[22, 23]. Commonly, knee OA gait patterns exhibit reduced knee flexion and abnormal knee adduction angle, which is more related to the loading area of medial and lateral knee compartment of knee joints.[15, 21]

There are many physical therapies utilized in the treatment of knee OA, such as muscle strengthening exercises and joint mobilization.[24-27] Kinesio Tape™ is a relatively new modality which uses elastic cotton (100%) strip with acrylic adhesive capacity. Dr. Kenzo Kase, a Japanese chiropractor developed this method in the 1970s.[28] Kinesio Tape™ is activated by body heat, which allows quick dry, long usage time, and theorized to facilitates the involved muscle and joints function.[28, 29] This kind of tape is designed to allow a longitudinal stretch capacity, up to 120%-140% of its original length, which ensures the unrestricted mobility of the applied area.[26, 30] The proposed effects of Kinesio Tape™ include: 1) strengthen the weak muscle; 2) facilitate or restrict movement via cutaneous stimulation; 3) improve the circulation of exudates towards lymph nodes and ducts; 4) correction of joints positioning for easing muscle spasms; 5) reduction of pain by neural pathways. [31-36]

Different shapes of Kinesio Tape™ exert different effects and tailor to various muscles. Application of Kinesio Tape™ from the muscle's origin point to the insertion point facilitates muscles, and the opposite direction has inhibitory effects on muscle.[1] Proper tension of the

tape is another key factor for effective treatment.[37] The traction of this elastic tape is graded by the percentage: full tension 75%-100%; moderate tension 50%-25%; light tension (paper-off tension) 25%-15%.[38,39] In order to facilitate chronically weakened muscle or increase muscle activation, Kinesio Tape™ should be applied with 25%-50% tension.[38]

Previous research has demonstrated that Kinesio Tape™ improves knee proprioception and decreases pain among knee OA patients.[40-42] Additionally, Kinesio Tape™ improves muscle strength and joint ROM, which leads to better functional movements. [43] Normal gait pattern needs proper muscle activation and enough joint excursion. Some previous studies focused on the effect of Kinesio Tape™ on gait patterns for patients with lower extremities complaints. The conclusions mostly are that Kinesio Tape™ positively affects the kinematic and kinetic factors. [44-46] But there was no previous study about the effects of the Kinesio Tape™ on gait variables for knee OA patients in particular.

The main symptoms of knee OA is pain and knee pain is associated with knee dysfunction.[1-3] Therefore, the purpose of this study is to determine the effect of Kinesio Tape™ on gait patterns among individuals with knee OA related pain when the tape is applied on the quadriceps femoris muscle. The hypothesis is that the Kinesio Tape™ on the quadriceps femoris can relieve knee pain, improve the walking velocity, knee excursion, and improve the kinematic and kinetic variables among knee pain patients.

# CHAPTER 2. METHODOLOGY

## 2.1 Research Design

A repeated measures design was used to investigate the effects of Kinesio Tape™ application on the quadriceps femoris muscle to assess gait changes in individuals with knee OA related pain. The Kinesio Tape™ was applied on the quadriceps femoris, vastus lateralis, and vastus medialis with three I-shape tapes, respectively. Participants with knee pain were randomly assigned to the KT or sham groups, while healthy participants without knee pain were assigned to the control group. All participants completed the Knee Injury and Osteoarthritis Outcome Score (KOOS) before and after the completion of the study, prior to the Kinesio Tape™ application at each session, while participants only filled the pain subscale of KOOS during the second and the third data collection session. The outcome measures of gait in this study included walking velocity, knee kinematic and kinetic variables. The kinematic variables were the peak knee flexion angle (PKFA) during the stance phase, KFA at the initial contact (IC), and peak knee adduction angle (KAA) in the frontal plane during stance phase. The kinetic variables consisted of peak knee flexion moment (KFM), peak knee adduction moment (KAM), loading rate, and maximum vertical ground reaction force (GRF) in the stance phase. There were four time-points for data collection: baseline, immediately following the tape application (immediate post-tape), three days following the tape application (three days post-tape), and three days post-tape removal. At each data collection, the participant walked for at least six trails. We hypothesized that the Kinesio Tape™ would improve gait performance among knee pain participants

## 2.2 Participants

A total of 34 participants were recruited to join the current study, and each group consisted of 11 individuals except for the KT group. Knee pain participants who meet the

inclusion and exclusion criteria were randomly assigned to either the KT or the sham groups. Control participants' inclusion criteria was healthy individuals without knee pain and the exclusion criteria was the same as knee pain participants.

The KT group was 12 participants at the beginning. However, one participant of this group was allergic to the tape and, therefore, did not continue with the data collection. Moreover, another participant in the same group missed the third data collection but only the recorded walking part, therefore, the remaining parts of the data were utilized. The mean age of participants was 63.91 (18.04) years old, the mean height of all was 1.62 (0.11) m, and the mean weight was 70.65 (18.45) kg. (Table 1)

Since the knee OA patients with the radiographic diagnosis were difficult to find, the inclusion criteria were modified to include individuals with related symptoms of knee OA. The inclusion criteria were: 1) age over 18, 2) knee OA or related complaints, 3) knee pain with rest in the affected knee(s), 4) knee pain with regular movements in the affected knee(s), 5) pain and disabilities during activities of daily living (ADLs), 6) pain and /or limitations with stair negotiations, 7) stiffness in the affected knee(s). And the exclusion criteria were: 1) any other current lower limb injury, 2) open wounds around the knee or quadriceps area during the study, 3) demand of assistance during walking, 4) skin sensitivity to tape, 5) any neurological conditions, 6) rheumatoid arthritis of the lower body, 7) total knee arthroplasty, 8) current candidate for knee replacement surgery, 9) current low back pain, 10) inability to follow the instruction. Informed consent was obtained from each participant. The tape was applied on their most affected knee if their complaints were bilateral.

### 2.3 Kinesio Tape™ Application

The participants in the KT group had the Kinesio Tape™ adhered in three "I-shaped" pieces on their quadriceps muscles.[43] The tape tension was 50%, and tape length was

standardized by the concepts of this tape[38, 39]. The Kinesio Tape™ could be stretched to 120%-140% of its original length.[26] Therefore, 100% tension is when the tape is stretched to the maximum length (140% of its original length). In this case, 50% tension is 120% of its original length. The length of 50% tension was equal to the length of the covered area divided by 120%. Additionally, there are always two anchors, 5cm per anchor, at the edges of tapes and tare applied without tension. Therefore, the length of the covered area should subtract 10cm firstly. Then, the total length of each applied tape was equal to length of 50% tension plus two anchors (Figure 1 & 2).

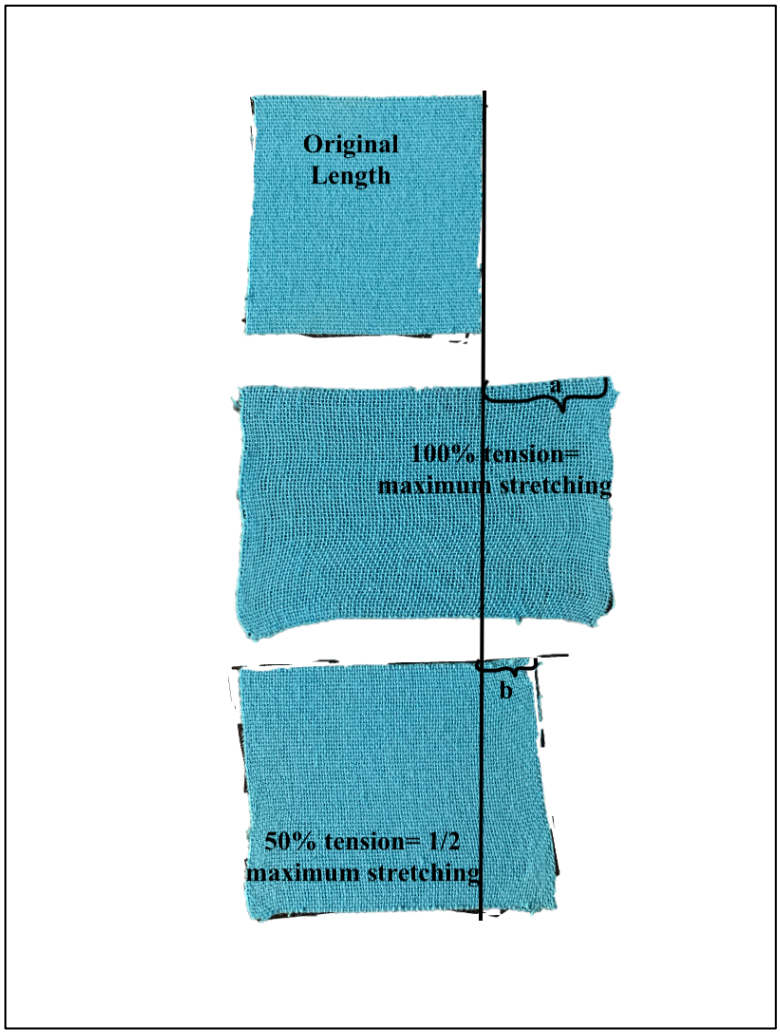


**Figure 1 The Definition of Tape Length**

**(Maximum stretching: stretch the tape to 140% of its original length; b = ½ a)**

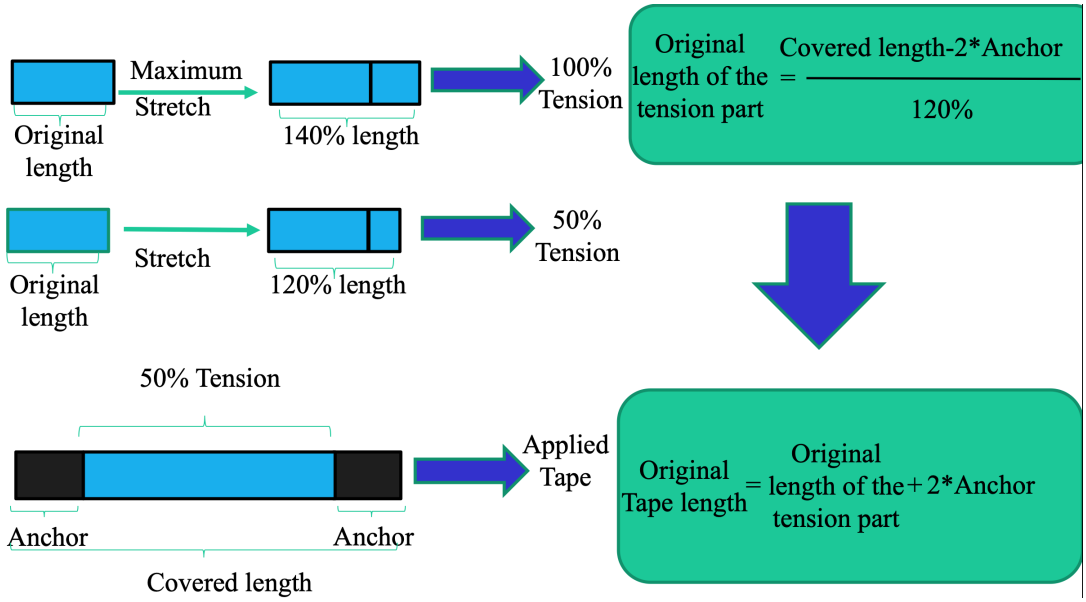


**Figure 2 The Calculation Method of the Tape Length**

The starting position of participants was supine and kept their knees extension. The lengths of covered areas were measured for every participant at the baseline. The first tape was applied on the rectus femoris from the 10cm below the anterior superior iliac spine(ASIS) to the superior border of the patella. The base of this tape was applied 10 cm below the ASIS without tension and then pulled alongside the course of rectus femoris to the superior border of the patella. And then, participants bent their knees at 45 degrees measured by a goniometer, and the rest tape was paper off extending over the superior border of the patella. The base of the second I-shape was applied below the greater trochanter following the course of the vastus lateralis to the lateral border of the patella when participants were back to the starting position. Then, the knee kept flexing at 45 degrees with the remaining tape applied with the paper-off tension around the lateral edge of the patella towards the tibia tuberosity. The third tape was from the proximal 1/3rd of the medial side of the thigh to the medial border of the patella following the course of the vastus medialis. The rest of the strip was applied without tension after participants flexing knees at 45 degrees towards the tibia tuberosity. (Figure 3)

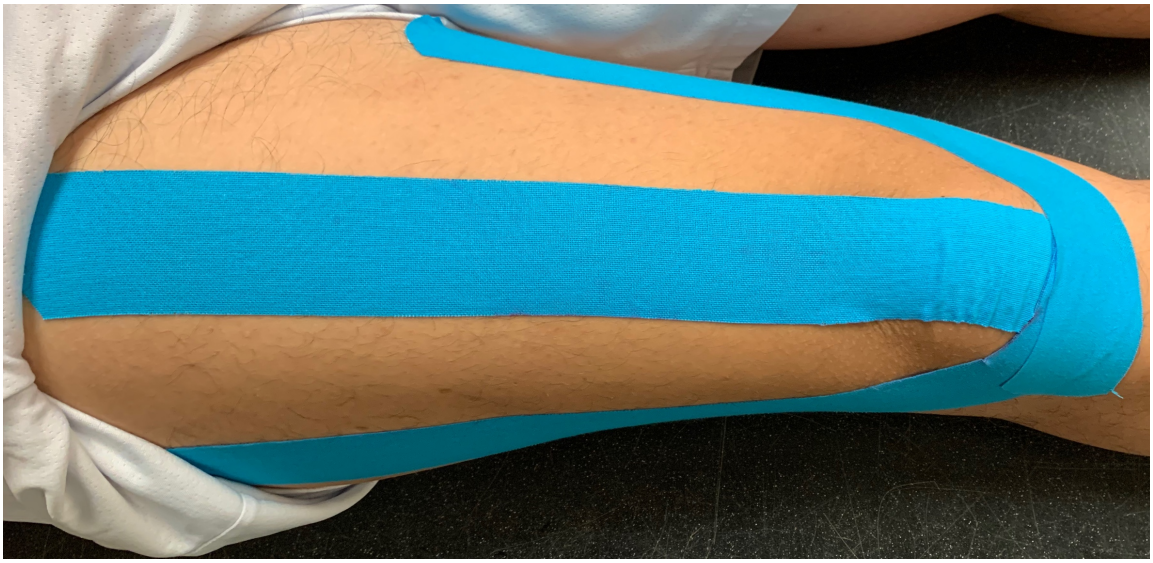

**Figure 3 The Quadriceps Facilitation Kineiso Tape™ Method**

For the sham group, only one I-shaped Kinesio Tape™ was applied on the rectus femoris without tension. The length of this tape was measured from 10 cm below the ASIS to the superior border of the patella following the course of the rectus femoris. (Figure 4) Participants kept knee extended in supine position. In the control group, the participants received the same three tapes as the KT group. Kineiso Tape™ was applied on the dominant legs for the control group, while KT and sham groups received Kineiso Tape™ on the affected legs. If affected leg are bilateral, the tape was applied on the more severely affected leg. Tapes were kept on the skin at most for 72 hours, but participants were instructed to remove it if they have skin irritation or there was excessive peeling. One participant was allergic to this tape, and a few participants felt a little itch at the edges of tapes. Most participants kept the tape well for 3-day, while the middle tape was most likely to peel.

The lengths of medial, lateral, and median thigh-length were measured by a tape ruler at the baseline. The Kinesio Tape™ was applied by a certified Kinesio Tape™ examiner in this study.

**Figure 4 The Tape Method for Sham Group**

## 2.4 Questionnaires:

As a part of the baseline, all participants filled the Knee Injury and Osteoarthritis Outcome Score (KOOS), a self-reported questionnaire that describes participant symptoms and functional limitations.[47] There are five subscales of KOOS: pain, symptoms, ADL, sport and recreation function (Sport/Rec), and quality of life (QOL). For each question, the score range is from 0 to 4. Furthermore, the maximum score of each subscale is 100, which indicates no symptoms and great knee function, while 0 score indicates the extremely severe symptoms. Furthermore, in order to assess pain, the pain subscale was extracted and was assessed at every data collection.

In addition, all participants answered a question before markers application at each data collection. Participants were asked if they feel knee pain now. The answer options were from KOOS pain, which is none, mild, moderate, severe, and extreme. Participants chose one level, depending on how they feel their knee pain.

**2.5 Gait analysis:**

A total of 31 retro-reflective markers were placed on specific anatomical landmarks on participants prior to walking trials. The locations of these retroreflective markers were bilaterally at the 1st, 2nd and 5th metatarsophalangeal (MP) joints, base of 5th metatarsal, medial malleolus, lateral malleolus, posterior calcaneus, medial femoral epicondyle, lateral femoral epicondyle, anterior superior iliac spine, dorsal superior iliac spine, and acromioclavicular joint; unilaterally at the - jugular notch, xiphoid process, C7 spinous process, T10 spinous process, inferior angle of right scapula. Four rigid arrays of markers were located bilaterally on the mid-thigh and mid-shank. The bilateral medial malleolus, bilateral medial femoral epicondyle, and bilateral 1st MP joint markers were removed after a standing calibration.

The 3D motion was captured by a motion capture system (Vicon Motion Systems, Vicon LA, Culver City, CA USA), including 18 cameras to capture marker trajectories and a force plate (Advanced Mechanical Technology, Inc., Phoenix, AZ, USA) to measure ground reaction forces. The kinetic joint moments were calculated by using inverse dynamics. Data were processed with Visual-3D v4 software (C-Motion, Inc., Germantown, MD).

Participants were instructed to walk barefoot at a self-selected velocity. There were six successful walking trials, three for each foot, at each data collection time point. A trial was successful when the entire foot landed on the force plate. The length of the walking path for recording was 4 meters, marked by two sets of infrared timers, but the actual walking length was a little longer. The extra track was to adjust the distance to the force plate to make sure that the entire involved foot could land on the force plate as naturally as possible. The infrared timer (Speed Trap II, Brower Timing Systems, Draper, UT) was used to record walking time. It started once the participants crossed the start line indicated by an initial "beep" and stopped once the participants crossed the 4-meter mark indicated by the second "beep". The participant

kept the eyes on the white "X" marker on the laboratory wall 15.5 cm away from the starting points during the walking procedure. They walked back to the same starting position and begun the next trial.

**2.6 Data reduction:**

This research only focused on the knee joint; therefore, the kinematic and kinetic data of the knee joints were analyzed. The ROM kinematic variables of interest were the knee flexion angles (KFA) at initial contact (IC), peak KFA (PKFA) in the sagittal plane, and peak knee adduction angle (PKAA). The peak knee external flexion moment (PKFM), peak knee external adduction moment (PKAM), maximum vertical ground reaction force (vGRF), and loading rate in the stance phase were the kinetic variables of interest. The loading rate, defined as the average slopes of the GRF curve immediately following heel strike during walking.[11]

**2.7 Procedures:**

There were 4-time data collections in 10 days. On the first day, the baseline data collection, participants were informed and then signed the consent form. Then they filled the whole Knee Injury and Osteoarthritis Outcome Score (KOOS). Next, their height, weight, and the median, lateral, and medial lengths of the affected thigh were all measured. After that, 31 retroreflective markers were attached to the participants' bodies by the same experimenter every time. Next, they walked for several times in the recording place to collect three successful walking trials per foot as the baseline of their gait patterns.

After 72 hours, immediate post-tape time point, participants filled the pain subscale of the KOOS part. After measured the height and weight again, the tapes were applied on participants by a certified Kinesio Tape™ practitioner. After the Kinesio Tape™ and sham Kinesio Tape™ application and application of retro-reflective markers, another six successful

walking trials were recorded immediately. Three days post-tape application, the tapes were removed when participants came, and then they repeated all the same steps as the second data collection. A 72-hour "wash-out" period was followed. At the last data collection, in addition to the six successful walking trials, participants completed KOOS again. The whole process was ideally completed in ten days period, but the break time was adjustable depending on participants' available time (Table 1). Participants were re-taped if they prefer in the end. Most of the participants with knee pain preferred to accept the tape application again.

Table 1 The Break Time of Each Group

| | | Mean | Std. Deviation |
|---|---|---|---|
| Break Time-1 (day) | Con | 4 | 2.2 |
| | KT | 3.7 | 1.3 |
| | Sham | 6.5 | 9.6 |
| Break Time-2 (day) | Con | 3.4 | 0.5 |
| | KT | 3.3 | 0.5 |
| | Sham | 3 | 0.5 |
| Break Time-3 (day) | Con | 3.4 | 0.5 |
| | KT | 3.5 | 0.5 |
| | Sham | 3.5 | 0.7 |

1 meaning the break time between baseline and immediate post-tape;
2 meaning the break time between immediate post-tape and 3 days post-tape;
3 meaning the break time between 3 days post-tape and 3 days post-tape removal

**2.8 Statistical analyses**

A Mixed-Method Analysis of Variance (ANOVA) was used to assess the group effect (KT, sham, and control), time effect (baseline, immediate post-tape, three days post-tape, and three days post-tape removal) and group x time interaction effect on KOOS parameters and gait variables. Gait variables included PKFA in the sagittal plane during the stance phase, KFA at the IC, PKAA, walking velocity, PKFM, PKAM, loading rate, and GRF in the stance phase on the taped legs. The repeated measures ANOVA and one-way ANOVA were used to further analyze with significant time x group interaction effects. The data was analyzed using SPSS Version 26.0, with an alpha level of $p < 0.05$.

## CHAPTER 3. RESULTS

The descriptive statistics of demographic information for participants are presented in Table 2.

Table 2. Baseline demographic for all groups

| | Control Group | KT Group | Sham Group |
|---|---|---|---|
| Number of subjects (n) | 11 | 11 | 11 |
| Age (year) | 51.5 ± 20.5 | 69 ± 15.8 | 71.8 ± 10.6 |
| Height (m) | 1.7 ± 0.1 | 1.6 ± 0.1 | 1.6 ± 0.1 |
| Weight (kg) | 70.5 ± 15.1 | 66.5 ± 22.6 | 73.4 ± 19.4 |
| BMI ($kg/m^2$) | 25.6 ± 5.8 | 25.6 ± 7.2 | 28.5 ± 5 |
| Gender (male: female) | 5/6 | 2/10 | 2/9 |
| Side (left: right) | 1/10 | 6/6 | 7/4 |

The number showed as the Mean ± SD; N/A: Non-applicable.

### 3.1 KOOS Outcomes

The main effect for KOOS pain was significant ($F = 10.404$, $p < 0.001$) between groups (Table 5). In the pairwise comparisons, the KOOS pain was significant between the control and the KT group, and between the control and sham group, at each time point. However, there was no significant difference between the KT and the sham group (Table 7). There were no significant time effects for KOOS pain, indicating that pain level did not change over time (Table 8).

The remaining components of KOOS (symptom, sport and recreation, ADL, and QOL) were all significant ($p < 0.05$) between groups (Table 6). In particular, these KOOS components were all significantly different between the control and the KT group and between the control

and sham group ($p < 0.05$) (Table 9). There were no time effects on these KOOS components indicating no changes over time.

Table 3 Descriptive Statistics of KOOS Variables for Control, KT, Sham Groups at Each Time Point

| Outcomes | Time | CON | KT | SHAM | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Pain | 0 | 94.7(4.7) | 72.6(4.7) | 68.8(4.7) | 73.3 | 84.2 |
| | 1 | 96(4.3) | 73.0(4.3) | 69.6(4.3) | 74.4 | 84.6 |
| | 2 | 97.6(4.2) | 76.7(4.2) | 72.0(4.2) | 77.1 | 87.1 |
| | 3 | 96.3(4.9) | 74.8(4.9) | 73.5(4.9) | 75.7 | 87.3 |
| ADL | 0 | 97.6(4.8) | 75(4.8) | 72.5(4.8) | 76.1 | 87.3 |
| | 4 | 97.6(5.2) | 76.9(5.2) | 76.8(5.2) | 77.5 | 89.8 |
| QOL | 0 | 89.2(5.9) | 39.2(5.9) | 45.5(5.9) | 51 | 64.9 |
| | 4 | 89.2(6.0) | 45.5(6.0) | 52.3(6.0) | 55.3 | 69.4 |
| Sport/ Rec | 0 | 95.9(5.3) | 75(5.3) | 72.2(5.3) | 74.8 | 87.3 |
| | 4 | 95.9(5.9) | 78.2(5.9) | 76.8(5.9) | 76.7 | 90.5 |
| Symptom | 0 | 93.8(4.8) | 66.2(4.8) | 69.2(4.8) | 70.7 | 82.1 |
| | 4 | 94.8(5.2) | 69.2(5.2) | 71.8(5.2) | 72.5 | 84.7 |

N/A: Non-applicable; Rec: recreation; CON: control group; KT: experiment group; Sham: sham group; All descriptive numbers in each group showed as Mean (SD);0: baseline time point; 3: 3 days post-tape removal.

### 3.2 Gait Variables Outcomes

The time main effect of walking velocity was significant ($F = 5.428$, $p = 0.002$) (Table 15). The pairwise comparisons revealed that all groups walked significantly faster at third ($p = 0.008$, three days post-tape) and fourth ($p = 0.002$, three days post-tape removal) data collection time points compared to baseline. Regarding walking velocity, there were no group effects and no group x time interaction effect.

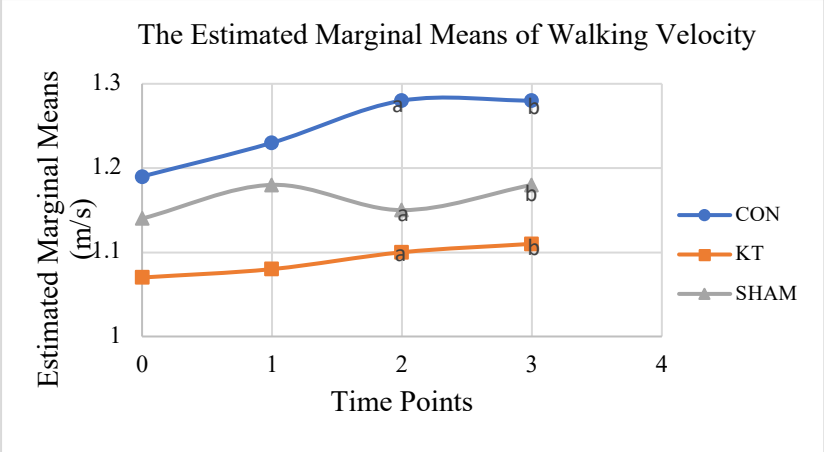


**Figure 5 The Trend of Mean Value of Walking Velocity of Each Time Point in Each Group**

**a &b: Indicates Significant Different from Time Point 1 ($p < 0.05$)**

The group x time interaction effect for loading rate (F = 2.241, $p$ = 0.052), PKFA (F = 2.532, $p$ = 0.027) and PKAA (F = 3.489, $p$ = 0.004) were statistically significant (Table 12). Repeated measures ANOVA, examining the time effects of variables in each group separately, indicated that in the control group, the loading rate significantly increased from the baseline to the three days post-tape time point ($p$ = 0.001) but reduced at the time point of three days post-tape removal ($p$ = 0.019) (Table 13 and Figure 6).

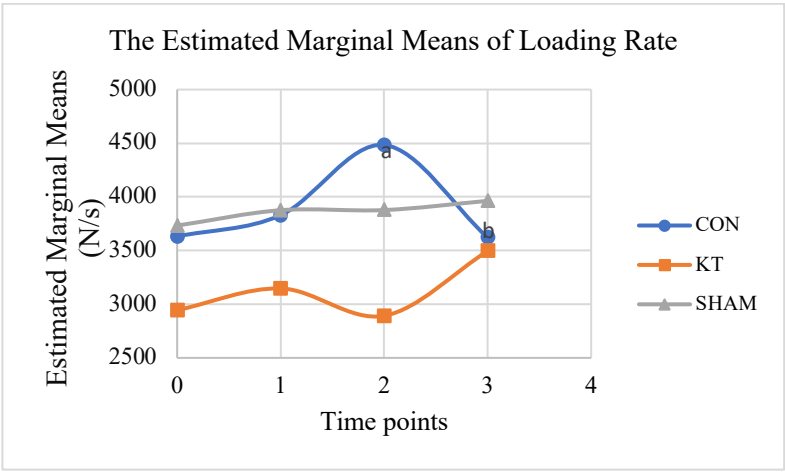


**Figure 6 The Trend of Mean Value of Loading Rate of Each Time Point in Per Group**

**a: Indicates Significant Different from Time Point 1 (p < 0.05)**

**b: Indicates Significant Different from Time Point 3 (p < 0.05)**

Pairwise comparison revealed the PKFA was only significant in the KT group when the baseline was compared with immediate post-tape ($p = 0.015$) and three days post-tape time points ($p = 0.031$) (Table 14). The PKFA in the KT group was decreased approximately by 3.87 degrees at immediate post-tape and three days post-tape time points compared to the baseline (Figure 7).

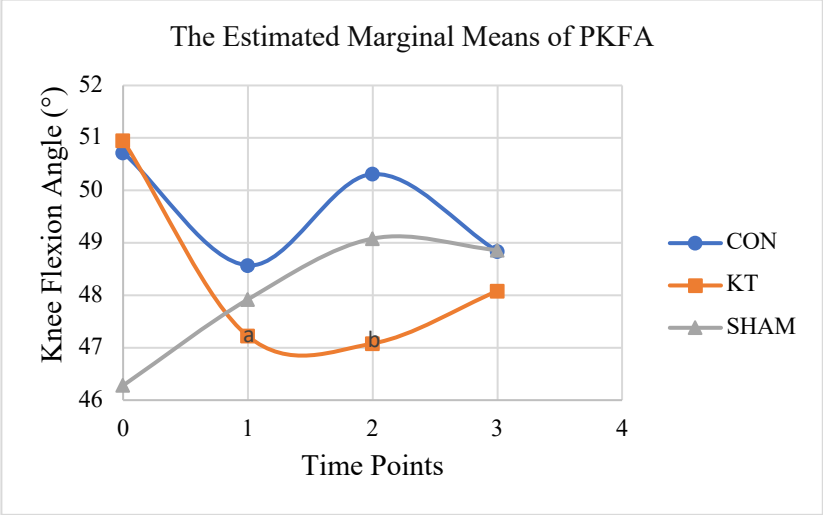


**Figure 7 The Trend of Mean Value of PKFA of Each Time Point in Per Group**

**a &b: Indicates Significant Different from Time Point 1 (p < 0.05)**

The PKAA was significant in both KT and sham groups (Table 14). The pairwise comparison of repeated measures ANOVA revealed that the PKAA for KT was significantly different when compared each of the first three time points with the fourth (three days post-tape removal) time points, indicating significant decrease in PKAA at the three days post-tape removal time point (Figure 8). The pairwise comparison also indicated that the PKAA of sham group significantly increased from immediate post-tape to three days post-tape removal time point ($p = 0.003$) showing opposite trend compared to the KT group.

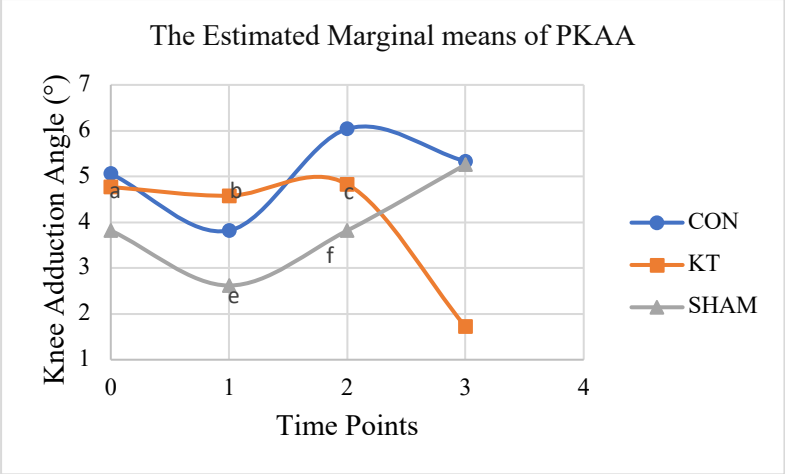


**Figure 8 The Trend of Mean Value of PKAA of Each Time Point in Per Group**

**a, b & c: Indicates Significant Different from Time Point 4 ($p < 0.05$); e & f: Indicates Time Point 2 was Significant from Time Point 4 ($p < 0.05$)**

There were no significant results between groups at each time point for all gait variables (Table 12), and no significant effects were found for the knee kinetic variables in the current study ($p > 0.05$).

Table 4 Descriptive Statistics of Gait Variables for Control, KT, Sham Groups at Each Time Point

| Outcomes | Time | CON | KT | SHAM | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| Walking Velocity (m/s)* | 0 | 1.2(0.1) | 1.8(0.1) | 1.1(0.1) | 1.1 | 1.2 |
| | 1 | 1.2(0.1) | 1.1(0.1) | 1.2(0.1) | 1.1 | 1.2 |
| | 2* | 1.3(01) | 1.1(0.1) | 1.2(0.1) | 1.1 | 1.3 |
| | 3* | 1.3(0.1) | 1.1(0.1) | 1.2(0.1) | 1.1 | 1.3 |
| GRF (N) | 0 | 780.6(50.9) | 713.9(53.4) | 776.3(50.9) | 695.8 | 818.0 |
| | 1 | 797.0(50.3) | 715.3(52.8) | 769.3(50.3) | 700.1 | 821.0 |
| | 2 | 797.1(48.7) | 716.4(51.1) | 769.6(48.7) | 702.5 | 819.5 |
| | 3 | 795.1(50.2) | 720.0(52.7) | 770.1(50.2) | 701.4 | 822.0 |
| Loading Rate (N/S)* | 0 | 3631.7(628.7) | 2944.6(659.4) | 3732.6(628.7) | 2681.7 | 4190.9 |
| | 1 | 3829.3(659.8) | 3146.9(692.0) | 3875.9(659.8) | 2825.5 | 4409.3 |
| | 2 | 4483.4(589.4)* | 2892.3(618.1) | 3877.3(589.4) | 3043.6 | 4458.4 |
| | 3 | 3621.4(636.5)* | 3495.9(667.6) | 3962.9(659.8) | 2929.33 | 4457.46 |
| PKFA (°)* | 0 | 50.7(1.9) | 51.0(2.0) | 46.3(1.9) | 47.1 | 51.6 |
| | 1 | 48.6(1.7) | 47.2(1.7)* | 47.9(1.7) | 45.9 | 49.9 |
| | 2 | 50.3(1.6) | 47.1(1.7)* | 49.1(1.6) | 46.9 | 50.7 |
| | 3 | 48.8(1.7) | 48.1(1.7) | 48.9(1.7) | 46.6 | 50.6 |
| KFA at IC (°) | 0 | 11.5(1.9) | 13.5(2.0) | 10.8(1.9) | 9.7 | 14.2 |
| | 1 | 10.6(1.9) | 10.7(2.0) | 11.1(1.9) | 8.6 | 13.1 |
| | 2 | 11.9(1.6) | 10.3(1.6) | 12.6(1.6) | 9.7 | 13.5 |
| | 3 | 9.1(2.0) | 11.3(2.1) | 11.4(2.0) | 8.2 | 13.0 |
| | 0 | 0.8(0.08) | 0.8(0.08) | 0.7(0.08) | 0.6 | 0.8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| PKFM (N*m) | 1 | 0.9(0.08) | 0.7(0.08) | 0.7(0.08) | 0.7 | 0.8 |
| | 2 | 0.9(0.08) | 0.7(0.09) | 0.7(0.08) | 0.7 | 0.9 |
| | 3 | 0.8(0.08) | 0.7(0.08) | 0.7(0.08) | 0.7 | 0.9 |
| PKAA (°)* | 0 | 5.1(1.1) | 4.8(1.2)* | 3.8(1.1) | 3.2 | 5.9 |
| | 1 | 3.8(1.3) | 4.6(1.4)* | 2.6(1.3)* | 2.1 | 5.2 |
| | 2 | 6.0(1.2) | 4.8(1.3)* | 3.8(1.2)* | 3.4 | 6.4 |
| | 3 | 5.3(1.5) | 1.7(1.6) | 5.3(1.5) | 2.3 | 6.0 |
| PKAM (N*m) | 0 | 0.5(0.04) | 0.5(0.04) | 0.4(0.04) | 0.4 | 0.5 |
| | 1 | 0.5(0.05) | 0.5(0.05) | 0.5(0.05) | 0.4 | 0.5 |
| | 2 | 0.5(0.04) | 0.5(0.04) | 0.5(0.04) | 0.4 | 0.5 |
| | 3 | 0.5(0.05) | 0.5(0.05) | 0.5(0.05) | 0.4 | 0.5 |

CON: control group; KT: experiment group; Sham: sham group; All descriptive numbers in each group showed as Mean (SD); * the mean difference is significant at the .05 level, and the *p* values are in the tables in appendix. 0: baseline time point; 1: immediate post-tape; 2: 3 days post-tape; 3: 3 days post-tape removal.

## CHAPTER 4. DISCUSSION

Our results indicated no Kinesio Tape™ effect on knee pain and function measured by using KOOS and did not support previous research indicating beneficial effects of Kinesio Tape™ on pain immediately after applying tape on the quadriceps muscles for knee pain patients.[47, 40, 48, 49] KOOS is a valid and reliable self-assessment instrument aiming to evaluate the short-term and long-term follow-up of several knee injuries and osteoarthritis.[47] All KOOS parameters in the current study showed significant group differences at each time point, indicating that the subjects in both KT and sham groups indeed suffered from knee problems and had lower pain level and less functional disability. A systematic review of KOOS results of people with knee OA, ACL injuries, and focal cartilage lesion reported that the average score of KOOS of knee OA was the lowest.[47] The average scores of the subscale pain, symptoms, and ADL were around 52, and the average QOL was around 35, followed by the lowest scores for subscale sport/ recreation (approximately 22).[47, 50] In the current study, participants with knee OA related symptoms scored higher on all KOOS subscales (Table 2-3) than knee OA diagnosed patients from the systematic review[47]. Although KT and sham groups' level of knee pain and functional disability were higher than matched controls, it is possible that the severity of knee pain and disability in KT and sham groups in the current study were not high enough to show differences overtime.

Walking velocity only had time effects for all groups in this study, meaning, all subjects walked faster after tape application over time. Several prior studies reported that Kinesio Tape™ improved the walking velocity with the muscle facilitation tape method.[7,8] Learning effects might explain why all groups in the current study increased walking velocity. The walking path of the study was only 4-meters, and participants could have become more familiar with the experimental procedures over time. Furthermore, a similar study compared the effects

of this tape method on walking velocity over a 10-meter walking test (10MWT) at three time points: before tape application, one day after tape application, and three days after tape application.[53] Though this walking path was longer, all participants, including individuals in the control group, walked faster in 10MWT after the 3-day tape application. These results, along with the current study results, suggest that there is no effect of the Kinesio Tape™ for walking velocity.

The current results found that PKFA significantly decreased from baseline to three days post-tape, but only in the KT group. Previous research on PKFA has produced variable results. Some previous studies reported that the knee OA patients exhibited an increased KFA at IC and presented larger PKFA before mid-stance or in the early stance phase.[54-56] The reason why knee OA patients produced abnormal KFA at IC and PKFA before the mid-stance phase may relate to the difference in the loading area.[20, 54, 57] Previous research found that KFA at IC was significantly increased in severe knee OA patients, concluding that increase KFA is associated with the progression of knee OA.[54]

Contrary to these findings, other researches had the opposite view that the KFA diminished in all stance phases due to the weak quadriceps muscle strength and compensation of pain resulting in walking with an extremely stiff knee.[12, 58] Other studies also reported the reduced PKFA in knee OA with severe knee pain and joint instability.[59, 60] However, all agree, that there is less knee excursion (change in knee angle from IC to PKFA[61]) in the sagittal plane for knee OA patients.[12, 20, 54-60] In the current study, PKFA in the KT group was not different from that of the controls at the baseline; therefore, it is inconclusive whether the effect of Kinesio Tape™ on the PKFA was positive.

Though PKAA in the current study was significantly different overtime within both KT and sham groups, the trend in the KT group was completely different from the sham group. In KT group, the KAA remained constant until the three days post-tape time point, where the

value decreased by approximately three degrees by the three days post-tape removal timepoint. At the same timepoints, the sham group had the opposite change to PKAA, the value increased by approximately two degrees. The KAA is one of the significant knee kinematic variables impacting knee OA progression and development.[56] Monil, K. et al. (2018) studied the changes of KAA the changes of KAA and compared healthy participants to participants with either medial knee OA or lateral knee OA.[62] However, the conclusion was not very clear because the authors only found that the KAA was the more sensitive parameter than KAM since KAA changed through the entire stance phase.[63] As with KAM, it is essential to assess KAA when considering the loading pattern of knee OA. [56] Our results indicate that the PKAA was significant overtime within both KT and sham groups, the trend in the KT group was completely different from the sham group. However, no difference in PKAA between knee pain groups and healthy control group at baseline makes our finding inconclusive. Additionally, the discrepancy in the trend of PKAA for the KT and sham groups, might be attributable to the different joint loading in the knee pain participants within the current study. The inclusion criteria in the current study did not specify the anatomical location of knee OA or knee pain location, and this broad inclusion of participants might explain the opposite changes to PKAA over time in different groups.

It was previously demonstrated that KAM could be interpreted as a surrogate factor for loading distribution between medial and lateral knee compartments.[54] Higher KAM was found in knee OA patients, particularly for medial knee OA patients, which is associated with faster progression.[62] Based on the previous findings, our hypothesis was that the Kinesio Tape™ would decrease the PKAM in the KT group, assuming the knee pain group had high KAM. However, our results did not support our assumption of higher PKAM at the baseline in knee pain participants, and subsequently KT effect of decreasing the PKAM.

This study measured both acute effects and the long-term effects (3 days post-tape) of Kinesio Tape™. Previous studies[28, 64] reported that 3-days following Kinesio Tape™ application participants had stimulated the soft tissues, improved muscle strength, and increased the blood circulation and lymphatic drainage.[28] The results of the present study are not consistent with these findings. The present study also explored the long-lasting effects of the Kinesio Tape™, three days post-tape removal time point, and various gait variables, but there were no significant results.

The main limitations of this study were the sample size and knee pain severity. Due to recruitment constraints, it was challenging to find knee OA patients with a medical diagnosis. Therefore, the inclusion criteria were broadened to include participants with symptoms of knee OA versus the necessity of a confirmed radiographic diagnosis. The participants with knee pain in this study had relatively higher KOOS scores, and it was possible that the knee pain was not be severe enough to make significant gait changes.

Moreover, the tape method used in the present study was the quadriceps muscles facilitation approach aiming for the quadriceps femoris weakness commonly seen in knee OA patients. However, it is unknow if the participants with knee pain in our study actually had the quadriceps femoris weakness. In addition, most previous Kinesio Tape™ studies did not specify the definition of tape tension application. In the absence of the specifications on tape tension, in order to operationally define tape tension, we defined the 50% tape tension mathematically. However, the actual tension could be different from previous studies . Lastly, another limitation of the current study might have been the decision to remove the tape prior to the long-term effects time point walking trials, which could have altered the long-term effect outcomes.

## CHAPTER . CONCLUSION

Kinesio Tape™ changed the kinematic variables, PKFA and PKAA, over time. There were no significant differences for any of the kinetic variables or on pain in individuals with symptomatic knee pain acutely after and 3 days after tape application. The current study demonstrated a change in PKFA and PKAA over time, but it remains unclear if this change is beneficial or not. Furthermore, it is difficult to make sense of the current results because to the best of the authors knowledge, this is the first study to analyze the impact of Kinesio Tape™ on gait variables for knee pain patients. Hence, this study revealed that Kinesio Tape™ impacts gait kinematic variables, but its therapeutic effects needs further research. It also remains unclear, whether the long-term effects of the Kinesio Tape™ application are stronger than the acute effects of tape application. Future research should focus on the effects of KT on more severe knee OA patients with longer study duration for gait variables, especially the kinetic variables.

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# CHAPTER 4. LITERATURE REVIEW

Knee osteoarthritis (OA) is one of the common diseases in older people causing disability and functional limitations. [40] Thus, people with knee OA have different gait patterns from healthy people. Kinesio Tape™ was created by Dr. Kenzo Kase in the 1970s and was wildly used since the 2008 Beijing Olympics. Dr. Kendro introduced that Kinesio Tape™ increase proprioception, realign fascial tissue function, increase the joint range of motion, correct muscle function, decrease pain, and improve muscle performance as well as muscle strength. [65] Kinesio Tape™ is often seen as a standard treatment and prevention approach for musculoskeletal disease. However, current research about Kinesio Tape™ focused more on the effect of Kinesio Tape™ on different muscle groups to ease the pain and improve the proprioception. There is less research related to the effect on gait performance.

## 4.1 The quadriceps weakness in knee OA

Sheila C O'Reilly et al., (1998) [65] determine the importance of femoris strength of knee OA concerning pain and disability. There were 300 patients with pain and 300 patients without pain in this study. WOMAC questionnaires measured pain and limitations. Quadriceps femoris strength was assessed by a modified Tornvall chair, which was a chair that estimated the maximum voluntary contraction (MVC). Participants sit on the chair with knee and hip flexing at 90 degrees. A strap placed above the right medial malleolus (the affected leg) was connected to a strain gauge to test the MVC. A technique of twitch superimposition evaluated the quadriceps femoris activation. Electrodes were placed on the anterior thigh with a high voltage stimulator. The voltage was adjusted to stimulate around 20% of maximal quadriceps femoris strength. Participants were asked to do the maximal contraction with this twitch three times to calculate the maximal predicted contraction (MPC). Patients with pain had more severe

quadriceps femoris weakness than patients without pain, so they gained conclusions that: quadriceps femoris weakness was evident in knee OA and highly related to pain.

Knee OA is associated with knee joint instability due to the impaired quadriceps femoris strength. To maintain joint function, knee OA patients usually generate compensatory muscle activity. Unlike other studies which only focused on measuring the isometric and isotonic quadriceps femoris muscle strength, Hortobágyi T. et al., (2005) [9] paid attention to the alternative activity pattern of muscles surrounded knee joint when subjects with knee OA did activities of daily lives (ADL). This is a non-randomized case-control study. They compared muscle activation patterns of unilateral knee OA patients with healthy young adults. The study was separated into two parts. The targeted muscles were fibularis head, vastus lateralis, the biceps femoris, tibialis anterior, and gastrocnemius lateralis. Two single-use diagnostic ECG electrodes were attached to each muscle. They recorded the surface EMG activities from specific muscles during level walking, stair ascent, and stair descent. The second part was the maximal EMG activity study. Subjects performed unilateral maximal voluntary isokinetic contractions on a dynamometer with ECG electrodes on targeted muscles as the maximal EMG activity. The EMG data were collected by the TeleMyo telemetric hardware system (Noraxon USA, Inc., Scottsdale, AZ, USA). Two coactivity ratios were computed, the biceps femoris to vastus lateralis ratio (BF/VL) during the ADLs, and the ratio of the biceps femoris EMG activity relative to the maximal EMG activity of biceps femoris eccentric and concentric contraction (BF/BFmax). Results showed that the knee OA patients had higher coactivity than healthy and young adults due to the greater BF/VL and BF/BFmax of OA. The higher BF/VL ratio represented the low activation of the quadriceps femoris muscle in knee OA patients. Thus, when subjects with knee OA did ADLs, like level walking and stair negotiation, they relied less on the quadriceps femoris muscle.

### 4.2 The effect of Knee OA on gait pattern

Kaufman K. et al., (2001) [18] the gait characteristics of subjects with knee OA. 139 adults diagnosed with knee OA were involved in this study, with 47 males and 92 females. The walking conditions included the level of walking and stair negotiation. A motion-analysis system with six cameras (Expert vision-Motion Analysis Corporation, Santa Rosa, CA) was utilized to capture the kinetic and kinematic parameters. Kinetic and kinematic data were analyzed by OrthoTrak 4.0 (Motion Analysis Corp., Santa Rosa, CA). Kinematic and kinetic variables included walking velocity, knee flexion, and extension angles, knee extension and flexion moment, and ground reaction force (GRF). Knee OA patients had reduced external knee extensor moment. Due to slower walking velocity, patients had lower GRF, but they had a larger internal moment in stair walking procedure because of the larger GRF and more extended knee loading. However, there was no significant knee angle reduction in the sagittal plane in this study.

Astephen J. et al., (2008) [12] aimed to find the difference of gait variables on the hip, knee, and ankle between three clinically distinct levels of knee OA disease severity: asymptomatic, moderate OA, and severe OA. The severity of knee OA was assessed by Western Ontario and McMaster Universities (WOMAC) osteoarthritis index and Kellgren–Lawrence (KL) radiographic scores. The kinematic and kinetic variables were flexion/extension angles, the net external flexion/ extension moments, ab/adduction moments, and internal/external rotation moments at the hip, knee, and ankle joints. The walking velocity and joint range of motion (ROM) were two parameters decreasing with the level of severity. Severe patients had slower walking and less ROM compared with moderate knee OA patients. All knee OA patients had reduced early stance flexion moments and higher mind-stance adduction moments. Peak hip adduction moment and hip extension moment in late stance decreased. Only severe knee OA patients had knee extension moments in the late stance phase.

The purpose of Annegret Mundermann et al., (2005) [66] was to investigate the gait change of medial compartment knee OA of varying severity. They hypothesized that the gait changes of knee OA patients were highly related to the increased loading at the ankle, knee, and hip joint, especially the frontal plane. 46 participants were divided into four groups: less severe knee OA group, the related control group, more severe knee OA and the relevant group. WOMAC and K/L were the assessment to define the severity of the medial compartment knee OA. The gait process was recorded by using four high-speed cameras (120 frames/second, MCU240; Qualisys Medical, Gothenburg, Sweden). GRF, ankle maximum inversion moment, knee flexion and extension angles, knee adduction moment, first and second hip peak adduction moment, hip maximum abduction moment, and maximum axial loading rate of the ankle, hip, and knee were the outcome variables. The axial loading rate increased in all joints of the lower extremity. Lower hip adduction moments were found in patients with the more severe knee. They also had greater first peak knee adduction moments than their matched control subjects and then patients with less severe knee OA. Thus, patients with medial compartment knee OA landed with the knee in a more extension position and experienced a rapid increase in the GRF, which indicated a quick shift of the bodyweight from contralateral limb to the support limb.

Chehab, E. F. et al., (2014) [55] thought knee adduction moment (KAM) is not the only common factor that affects the joint loading within people with knee osteoarthritis. They decided to test both the peak knee adduction moment (KAM) and peak knee flexion moment (KFM) during the early stance phase and assumed that these two variables would both have effects on the knee cartilage changed over 5 years. 16 participants who had participated in a previous knee OA study 5 years ago were recruited in this study. Their kinematic data were collected by a multi-camera system (Qualisys AB, Gothenburg, Sweden) by doing 3 trails normal walking. The first peak KAM and KFM of the first half of the stance phase were determined as the main kinetic variables collected by the force plate (Bertec Corporation,

Columbus, OH). Every participant took MRI to define the cartilage thickness, while a modified version of the Rush Hospital for Special Surgery function knee evaluation was used to quantify the pain score. The Shapiro-Wilk test showed that the mean changes in medial-to-lateral cartilage ratio thickness were strongly associated with both KAM and KFM. This study elucidated that KAM is not the only significant moment that has adverse effects on medial cartilage degeneration. The increased KFM may correspond with the increasing loading in both medial and lateral compartments of patients with knee OA. The authors claimed that the KFM should also need to be considered as an aspect of intervention when treating knee OA.

KAM and the knee adduction angle (KAA) are two common biomechanics factors that are associated with knee OA progressive and development. Monil, K. et al., (2018) [62] determined that the additional element, the center of pressure (COP), could affect the KAA and KAM. The previous study indicated that the peal KAM could decrease by modifying the COP medially. [67] Therefore, the purpose of this study is to compare the position of COP, KAA, and KAM between subjects with and without knee OA, as well as investigating the relation among COP, KAA, and KAM. They used Vicon motion capture system (Vicon Motion Systems Ltd, Oxford, UK) and two Kistler Portable force plates (Kistler Type 9286B, Kistler Instrument AG, Winterthur, Switzerland) collecting the data of in total 108 individuals (84 health, 18 with medial knee OA, and 6 with lateral knee OA). They ask participants walking through a 6-m walkway and collect three times of clean heel strike on each plate with bare food and comfortable walking speed. They pick the KAA, KAM, and COP of three gait phases: 1) early-stance [initial contact to the first peak of ground reaction force (GRF)], 2) mid-stance [first peak GRF to the second peak GRF], 3) late-stance [second peak GRF until toe off]. One-way analysis of variance was applied to detect the significant differences between the group's KAA, KAM, and COP. They found that the KAA is the most sensitive parameter, which was close to zero within the healthy group, largest varus in medial OA group, and valgus deformity in the

lateral group in all three gait phases. In the meantime, KAM only presented differences among these three groups in the first gait phase, while the COP had differences in the first two phases in the medio-lateral direction (COPX). One of the most significant findings of this study was to determine the COP patterns, in which lateral OA patients had the most medial COP, while the COP in both medial and healthy groups tend to be on the lateral side. But it was not valuable to discriminate against the medial OA patients and healthy individuals.

It is widely accepted that knee OA patients have increased joint moment which reflects the increased joint loads, implicated in the disease progression. But Zeni Jr, J. A., & Higginson, J. S. (2009) [68] doubted that the rise of the joint moment was due to the fast walking speed instead of the disease development. Thus, they decided to study the relationship between the different severities of knee OA and the different gait velocity. The hypothesizes were: 1) with self-selected walking velocity, different severities of knee OA would demonstrate different walking patterns; 2) there would be no difference when individuals present the same walking speed. There were 3 groups of subjects in this study, 22 in the control group, 21 in the moderate group, and 13 in the severe group. Gait data collection consisted of three separate walking trails with three different walking speeds on a split-belt treadmill (Bertec Corp, Columbus, OH, USA) and a motion capture system (Santa Rosa, CA, USA). The three different walking velocities in this article include control speed (1.0 m/s), self-selected speed (determined by a 10m timed walking in the hallway), and fastest tolerable walking speed (fastest comfortable walking without a walker). They selected peak sagittal plane variables composed of hip, knee and ankle moments, knee flexion angles, frontal plane knee moments, peak vertical and anterior-posterior GRF, peak longitudinal knee joint reaction force (IRF), and vertical loading rate occurring from heel strike to ipsilateral heel strike. The difference between groups was analyzed by individual multivariate ANOVA for each speed, and individual MANCOVA with the addition of respect speed as a covariate was used to figure out the distinction between self-selected speed and fast

speed between groups, while repeated measures MANOVAs evaluated for differences in each group under the three different walking speed. The conclusion was that participants with different severities of knee OA have a walking speed-oriented characteristic associated with the gait parameters changes. With self-selected and fastest tolerable walking velocity, the differences could be seen in the majority of gait elements, whereas only the loading rate changed between groups when walking with control speed. This outcome is contrary to some of the previous research that the gait parameter differences result from mechanical changes along with the progression of knee OA. This kind of difference was partly due to the change in walking speed.

Henriksen, M. et al., (2010) [69] investigated the relationship between pain of the knee OA and the biomechanics changes of the related gait patterns. They used healthy people to replicate the knee pain induced in the infrapatellar fat pad and observe the gait changes. Also, they compared these changes with the gait patterns of less severity medial knee OA patients. 36 healthy participants (18 males and 18 females) were recruited from the public, while the gait information was from a previous study including 192 knee OA patients. The severity of the knee OA was measured by the radiographic K/L score. The study was divided into 2 parts, experimental and comparative. In the experimental part, the healthy people were injected into 3 types: a hypertonic saline injection pain, an isotonic saline injection as nonpainful control, and a sham injection. The gait was recorded by a 3-D motion capture system (Vicon MX, Oxford, UK) and two force platforms (AMTI OR 6-5-1000, Watertown, MA). Healthy subjects performed 3 series of walking trails under 3 conditions: baseline, during experimental pain, and 20 minutes after pain induction on 3 days separated by at least 1 week. The knee OA patients only walk on a series of trails on one day. Each series trail consisted of 5 walking trails. The pain was examined by the VAS and pain score of KOOS. The variables they felt interested in were in the stance phase of the gait cycle, containing KFA at heel strike, maximum KFA

during early stance, and minimum flexion in late stance, peak internal sagittal knee joint moments, and peak external frontal plane knee joint moments. The analysis methods were repeated measures MANOVA for healthy subjects and a 2-sample t-test for comparing the difference between healthy people and less severity of knee OA patients. The first conclusion was the changes of healthy participants who got pain injections showed lowered frontal and sagittal plane knee joint moments similar to the less severe medial knee OA patients. They found the gait changes are similar to previous researches. But this study suggested that pain is an important factor that affects the walking mechanism, and it is not necessary to conclude that the gait changes are due to the mechanical pressure of medial cartilage since there are no pain receptors in the articular cartilage. They injected in the infrapatellar fat pad which created pain showed that the inflammation or pain in this area would result in the gait adaptation in knee OA patients.

The purpose of Heiden, T. L. et at., (2009) [54] was to find the different pf gait between knee OA patients and asymptomatic control people, determine the level and net muscle activations, and examine two directed co-contraction ratios. The muscle groups are medial and lateral quadriceps, hamstrings and gastrocnemius muscles, and medial and lateral hamstring muscles. In addition, they also investigated the relationship between muscle directed co-contraction and the gait parameters changes. There were 30 individuals in the control group and 54 in Knee OA patients. The KOOS and the medical Outcome Study 36-item short-form health survey (SF-36) were used to test the self-perceived knee pain and disability, while the gait data were collected by walking a 10-m walkway. Control people walked in 3 velocities: self-selected, slow, and very slow, whilst knee OA people walk with their self-selected speed. Each speed was captured at least 6 trails. The motion capture system (Oxford Metrics, Oxford, UK) and two AMTI force platforms (AMTI, Watertown, MA, USA) were used to collect kinematic and kinetic data. EMG data were recorded by the EMG system (Delsys, Boston,

MA). They collected EMG data from rectus femoris (RF), vastus medialis (VM), biceps femoris (BF) of hamstring, semimembranosus (SM), medial gastrocnemius (MG) and lateral gastrocnemius (LG). The kinematic variables included KFA at heel strike, peak KFA in early stance, and peak extension angle during mid-stance. Kinetic variables consisted of peak KAM during early stance, peak KFM in early stance, peak KFM in late stance, Peak KEM in loading, and late stance. And muscle co-contraction, they collected directed co-contraction ratios (DCCR) of agonists and antagonists, which determine the ratio od of these two muscle groups activation. In addition, they also record the net muscle activation. They separated the muscle as medial (SM, VM, MG)/ lateral (BF, VL, LG) muscles group, medial (SM)/ lateral (BF) hamstrings group, and knee flexor (SM, VM, MG, LG)/ extensor (VL, VM, RF). The t-test was used to test the between-group differences for ages, height, body mass, and walking speed. The non-parametric data was examined by the Mann-Whitney U-test, and at the men time, the analysis of variance (ANOVA) was used to compare between-group differences on the remaining dependent variables, such as co-contraction ratios, and gait variables. The relationship between muscle co-contraction and gait parameters of knee OA patients and controls, and between the self-perceived measures and gait parameters among these two groups were tested by the Pearson's correlations (r). The findings are a lot, and the first is about the walking velocity: the control subjects walking slow showed no significant differences compared with knee OA patients. OA patients displayed greater KFA both at the heel strike and during the early stance phase, but less KEA. For kinetic variables, OA patients revealed larger peak adduction levels in late stance as well as the larger KEM. The muscle con-contraction ratio showed that the OA patients had greater flexor and lateral muscle activation patterns. This concluded that muscle activation is varied even though small changes in kinematics and kinetics of gait. This article established the differences in medial/lateral patterns of muscle activation among knee OA group and controls. Knee OA patients exhibited a higher

level of lateral muscle activation in the stance phase of gait, which corresponding with the greater external KAM, could be a protective mechanism against pain.

Creaby, M. W. et al., (2012) [59] examined four different groups with knee OA patients in gait mechanics. The four groups were: 1) unilateral pain and structural OA; 2) unilateral pain, but bilateral structural OA; 3) bilateral pain and structural OA; 4)the asymptomatic control group. One-way ANOVA was used to examine group differences in gait variables of most asymptomatic limbs. Then the interlimb symmetry was assessed for each group. The one-way ACOVA was used to analyze walking velocity. The knee OA was classified with a K-L scale, while the anatomic knee alignment was measured using the posteroanterior radiographs. The average pain felt was assessed by the 11-point Likert scale numbered from 0 to 10. A Vicon motion analysis with 8 cameras was used to record the 5 walking trails with self-selected, normative walking speed. The main gait outcomes were PKAM, PKFM, knee varus-valgus angle, PKFA, toe-out, and trunk lean. the results showed that after controlling the walking aped, greater trunk lean was towards the painful knee and reduced KFA of the more painful knee in all knee OA patients. Between-knee asymmetries indicating greater varus angle and a lower external flexion moment in the painful knee were present in those with unilateral pain and either unilateral or bilateral structural OA. Knee biomechanics were symmetrical in those with bilateral pain and structural OA and the pain-free control group. Thus, pain unilaterally appeared with asymmetries in knee biomechanics. However, bilateral pain was related to symmetries.

Chen, C. P., et al., (2003) [14] investigated the sagittal GRF in different age groups and people with knee OA. Participants were divided into three groups: younger group with people at their 20s', and knee OA group with bilateral knee OA patients, and age-matched elderly group. Gait parameters were walking velocity, cadence, step length, stride time, single- and double support time, and sagittal ground reaction forces. The walking trails were collected with

a Vicon motion analysis system with 6 infrared cameras in a 10 meters walking path. The sagittal GRF variables included F1 (maximum force values under the hee), F2 (maximum force values under the toe), and M (minimum force values under midstance) for each group. the force change in the mid-foot was calculated by the formula: (F1 + F2)/2 – M. An univariate repeated-measures ANOVA was used for data analysis. The results reported that knee OA group had slower walking velocity, lower cadence, and longer stride time as compared with the elderly and young control groups  For GRF variables, knee OA group had longer first peak time, larger minimal midstance, and smaller second peak than both elder and younger groups. This elucidated that knee OA patients had longer double-support time. The force changes in the mid-foot region in the knee OA group and elderly group revealed more loading force into the mid-foot region during the midstance compared to the younger group. three were less heel contact and push-off forces in knee OA and elderly group.

### 4.3 The effect of Kinesio Tape™ on the gait

Aguilar-Ferrándiz et al. (2014) [44] investigated the effect of Kinesio Tape™ application on women with chronic venous insufficiency (CVI). Sixty-five participants were randomly assigned to the placebo group and the KT group, respectively. There were five strips attached on the shank. Two y-shaped tapes were applied on the gastrocnemius muscle. One I-shaped tape was used on the anterior tibia muscle. The last two I-shaped tapes were surrounded by the ankle joint. Subjects in the placebo group received an identical number of stripes with the same shape and positions. However, those strips were applied without tension, and the anatomic localizations were not correct. Participants accepted tape three times per week and experienced a 4-week intervention. The outcome measures were quality of life, the range of ankle motion (ROAM), especially the dorsiflexion angle, gait parameters, and pain. Gait parameters included cadence, stride length, step length, stand, and swing phase. The results showed that quality of

life was improved, gait parameters increased, and the ROM was significantly enhanced. Nevertheless, the pain was eased in both groups. Kinesio Tape™ was useful in improving the ROM and the gait, but for pain relief, Kinesio Tape™ may have a placebo effect.

Klejda T. et al. (2015) [45] evaluated the gait speed changes of old patients with knee OA while they were treated by Kinesio taping on the quadriceps muscle. 103 older people with knee OA were chosen in the patient's group, and 73 adults without knee complaints were assigned to the control group without pain. Kinesio Tape™ was applied with the maximal stretched tension by using a tonus regulation technique on the quadriceps femoris muscle for patients group and without tension on the same positions of participants in the control group. The time while participants walk for 10 meters with Kinesio Tape™ was calculated and asked them to walk for three trials. There were three data collections: before the Kinesio Tape™ application, one day after application and three days after application. Chi-square analysis was used to compare frequencies between groups. Continuous variables were presented as mean and standard deviation: mean ± SD (standard deviation). There was not a significant change in gait speed after one-day of Kinesio Tape™ application in both groups. There was a considerable change in gait speed needed to finish 10-meter walking after three-day of Kinesio Tape™ application in both control and patients' group. The gait speed changed significantly from one-day supplication to three-day of Kinesio Tape™ application in both groups.

The purpose of Rahlf, A. L. et al., (2018) [49] was to investigate the effect of Kinesio Tape on pain, knee function, knee ROM, quadriceps femoris muscle strength, balance ability, and walking ability. 230 knee OA patients were randomly assigned in three groups: the intervention, control, and sham groups. The intervention group received three I-shaped tapes around the patella, while the shame group only receive on strip distal to the knee joints. There is no tape application for the control group. The main outcomes were Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) subscales, and the secondary outcomes

are balanced, walking velocity, isometric torque, and ROM. Statistic balance was measured by the Balance Error Scoring System (BESS), whilst maximum walking velocity was calculated by the time participants to need for 10MWT.maximum isometric knee extension strength was assessed by using ab isokinetic dynamometer, additionally, the active ROM of knee flexion and extension was tested using a 360° double-armed goniometer. One-way ANOVA was used to compare the group difference in this study. At baseline, there were no differences in all outcomes between groups except for knee flexion. Significant effects were found for WOMAC pain, stiffness when compared to the intervention group with the controls. No interactions were found for balance, muscle strength, walking speed, or active range of motion. Wearing Kinesio tape for 3 consecutive days had beneficial effects regarding self-reported clinical outcomes of pain, joint stiffness, and function. This emphasizes that Kinesio taping might be an adequate conservative treatment for the symptoms of knee OA.

Park, J. S., et al., (2019) [51] hypothesized that Kinesiology tape (KT) would aid knee pain reduction, improve balance ability and enhance gait ability for older adults with knee OA. Only 10 participants with knee OA radiographic diagnosis joined in this study and was assigned to the KT group and control group (no intervention). The KT (BB Tape, WETAPE Inc., Pyeongtaek, Korea ) on both knees. A visual analogue scale (VAS) was used to assess pain. Walking ability was assessed by the time of 10 MWT (10 meters walking test). Besides, Dynamic balance ability was assessed with a timed up and go test (TUG). Wilcoxon signed-rank test was the main data analysis to compare the differences in the mean value for KT gait and non-KT gait. This result showed that the KT ease the knee pain and could improve the walking velocity since the waking time of 10 MWT decreased. And the authors believed that walking ability improvement was related to the pain relief effects of KT.

Tani, K., Kola, et al., (2018) [10]aimed to verify if the Kinesio Tape on quadriceps femoris muscle could change the walking speed in 10 MWT at normal speed for knee OA

patients and compared the acute tape effects and 3-day post-tape effects. 102 unilateral knee OA patients with diagnosis received quadriceps femoris facilitation tape methods, while 73 age-matched controls were applied sham tape. In conclusion, both control and knee OA group performed less walking time for 10MWT, thus, it is difficult to determine whether it is due to the Kinesio Tape effects or the placebo effects. It is a little different from the prior study which showed the kinesiology tape affected positively in 10 MWT.[51] This study also reported that the Kinesio Tape has better effects at three days post-tape than acute tape application.

### 4.4 The effect of Kinesio Tape™ on the quadriceps muscle

Cho H-y et al. (2015) [40] determined the outcome of Kinesio Tape™ on knee OA patients regarding the range of motion, proprioception, and pain. In total, 46 participants with knee OA were recruited from clinics. The Kinesio Tape™ was Y-shape, of which the main body was the I-shape applied on the quadriceps from the origin point to the edge of the patella, the muscle insertion point, with 15%-25%. And the Y-shape circled patella without tension. The author measured pain by using VAS scores collected in walking and at rest, the range of pain-free motion by using an inclinometer, and position proprioception through evaluating whether the patients can keep their knee at 60 and 90 degrees without visual help. The independent t-test was used to compare the effect of Kinesio Tape™ on pain, ROM, and proprioception. The Person correlation test was used to analyze the correlation between either pain and ROM or pain and proprioception. The significant improvement was found in each factor after the application of Kinesio Tape™.

The purpose of Figen K. et al. (2015) was to compare the effect of Kinesio Tape™ with that of sham taping for knee OA patients. [41] 22 participants were in the KT group, and 21 participants are in the sham KT group. The first Y-shape strip was applied when participants flexed their knees at the maximal angle. The base of the tape was on the top of the patella, and

the tail was stretched with 25% tension wrapping the patella. The fixed part of the second Y-shape strip was on the tibial tuberosity when participants' knees were flexed at 90 degrees. Tails wrapped the patella towards vastus medialis and vastus lateralis. The third strip was an I-shape applied when the knee was flexed at 30 degrees with 75% tension. Sham Kinesio Tape™ was the same without tension. It was the mediolateral direction in the middle of the patella. The pain was measured by VAS, the quality of life was evaluated by Nottingham Health Profile (NHP) that is a self-administered questionnaire used to quantify perceived health problem, and function of the knee was tested by Lequesne index which is designed to evaluate the severity for OA of the hip and knee. They found improvement in both groups. However, the score of NHP was higher in the KT group. They conclude that the effect of Kinesio Tape™ on knee OA is more beneficial than sham taping.

Ebru K. M. et al. (2017) [42] studied the effect of Kinesio Tape™ on pain, ROM of the knee and hip, function level, and critical lower extremities muscle strength for knee OA patients. [9] 42 individuals were randomly assigned to the KT group and the sham-KT group. The Kinesio Tape™ was applied to quadriceps muscle and hamstring muscle. The strip on quadriceps was the same as that of Chuo H-y et al. (2015). A Y-shape strip was applied on hamstring muscle from ischial tuberosity to the medial and lateral side of the back of the knee. The pain was evaluated by VAS during rest, walking, and night. Besides, the hip and knee extension and flexion angles were measured by a digital goniometer. The iliopsoas, gluteus medius, quadriceps femoris, and hamstring muscle strength were tested by a handle dynameters. Furthermore, the functional status of patients was evaluated using the Aggregated Locomotor Function score (ALF) and the Western Ontario and McMaster Universities Osteoarthritis scale (WOMAC). Those assessments were measured before Kinesio Tape™ application, initial after Kinesio Tape™ application, the third day after Kinesio Tape™ application (with Kinesio Tape™), and one month after application (without Kinesio Tape™). This article mentioned the

lasting effect of Kinesio Tape™ on both quadriceps and hamstring muscles. There were fewer improvements in hip ROM and all muscle strength. However, significant improvements were shown in the pain and function status of patients even after one month.

Knee OA patients have knee pain, muscle weakness, proprioception deficit, and functional limitation during ADLs. Thus, they have distinct gait patterns from ordinary people. The pain is related to muscle weakness, but we cannot conclude that they are causality, as the muscle weakness may be due to age. The most significant muscle weakness is quadriceps. Kinesio Tape™ can improve the performance of knee, including ROM, proprioception, pain, muscle strength, and walking velocity. So, Kinesio Tape™ is an excellent choice for the treatment of knee OA.

## Appendix A: Tables of significant values

Table 6 The Time, Group, and Interaction Effects of KOOS Pain

| Source | F | Sig. | Observed Power |
|---|---|---|---|
| Time | 2.152 | 0.107 | 0.5 |
| GROUP | 10.404 | 0* | 0.979 |
| Time * GROUP | 0.258 | 0.943 | 0.112 |

* The mean difference is significant at the .05 level.

Table 7 The Group Effects of the Rest four KOOS Variables

| Source | Measure | F | Sig. | Observed Power |
|---|---|---|---|---|
| GROUP | ADL | 7.026 | 0.003* | 0.901 |
| | QOL | 21.27 | 0* | 1 |
| | Sport/ Rec | 5.416 | 0.01* | 0.806 |
| | Symptom | 9.275 | 0.001* | 0.964 |

* The mean difference is significant at the .05 level

Table 8 Pairwise Comparisons of KOOS Pain Between Groups at Each Time Point.

| Time | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference* Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| 0 | CON | KT | 22.1* | 6.6 | 0.006* | 5.4 | 38.8 |
| | | SHAM | 25.9* | 6.6 | 0.001* | 9.2 | 42.6 |
| | KT | SHAM | 3.8 | 6.6 | 1 | -12.8 | 20.5 |
| 1 | CON | KT | 23.0* | 6.1 | 0.002* | 7.5 | 38.5 |
| | | SHAM | 26.5* | 6.1 | 0 | 10.9 | 42.0 |
| | KT | SHAM | 3.5 | 6.1 | 1 | -12.1 | 19.0 |
| 2 | CON | KT | 20.8* | 6.0 | 0.005* | 5.6 | 36.0 |
| | | SHAM | 25.6* | 6.0 | 0.001* | 10.4 | 40.7 |
| | KT | SHAM | 4.7 | 6.0 | 1 | -10.5 | 19.9 |
| 3 | CON | KT | 21.5* | 7.0 | 0.013* | 3.8 | 39.2 |
| | | SHAM | 22.8* | 7.0 | 0.008* | 5.1 | 40.5 |
| | KT | SHAM | 1.4 | 7.0 | 1 | -16.3 | 19.1 |

* Based on estimated marginal means

* The mean difference is significant at the .05 level. 0: baseline time point; 1: immediate post-tape; 2: 3 days post-tape; 3: 3 days post-tape removal.

Table 9 Pairwise Comparisons of KOOS Pain Among Four Time points Within Each Group

| GROUP | (I) Time | (J) Time | Sig. | 95% Confidence Interval for Difference* | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| CON | 0 | 1 | 1 | -6.6 | 4.1 |
| | | 2 | 1 | -12.5 | 6.8 |
| | | 3 | 1 | -8.8 | 5.7 |
| | 1 | 2 | 1 | -9.0 | 5.9 |
| | | 3 | 1 | -7.4 | 6.8 |
| | 2 | 3 | 1 | -6.6 | 9.1 |
| KT | 0 | 1 | 1 | -5.7 | 5.0 |
| | | 2 | 1 | -13.7 | 5.5 |
| | | 3 | 1 | -9.4 | 5.0 |
| | 1 | 2 | 1 | -11.2 | 3.7 |
| | | 3 | 1 | -8.9 | 5.3 |
| | 2 | 3 | 1 | -5.9 | 9.7 |
| SHAM | 0 | 1 | 1 | -6.1 | 4.6 |
| | | 2 | 1 | -12.8 | 6.5 |
| | | 3 | 0.5 | -11.9 | 2.6 |
| | 1 | 2 | 1 | -9.9 | 5.0 |
| | | 3 | 0.8 | -11.0 | 3.2 |
| | 2 | 3 | 1 | -9.3 | 6.4 |

Based on estimated marginal means; * The mean difference is significant at the .05 level; 0: baseline time point; 1: immediate post-tape; 2: 3 days post-tape; 3: 3 days post-tape removal.

Table 10 Pairwise Comparisons of the Rest Four KOOS Variables Between Groups at Each Time Points

| Measure | Time | (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| ADL | 0 | CON | KT | 22.6* | 6.8 | 0.007* | 5.5 | 39.7 |
| | | | SHAM | 25.1* | 6.8 | 0.002* | 8.0 | 42.3 |
| | | KT | SHAM | 2.6 | 6.8 | 1 | -14.6 | 19.7 |
| | 3 | CON | KT | 20.7* | 7.4 | 0.027* | 1.9 | 39.4 |
| | | | SHAM | 21.1* | 7.4 | 0.023* | 2.4 | 39.9 |
| | | KT | SHAM | 0.4 | 7.4 | 1 | -18.3 | 19.2 |
| QOL | 0 | CON | KT | 50.0* | 8.4 | 0* | 28.8 | 71.2 |
| | | | SHAM | 43.8* | 8.4 | 0* | 22.6 | 64.9 |
| | | KT | SHAM | -6.3 | 8.4 | 1 | -27.5 | 14.9 |
| | 3 | CON | KT | 43.8* | 8.5 | 0* | 22.3 | 65.2 |
| | | | SHAM | 36.9* | 8.5 | 0* | 15.5 | 58.4 |
| | | KT | SHAM | -6.9 | 8.5 | 1 | -28.3 | 14.7 |
| Sport/ Rec | 0 | CON | KT | 20.9* | 7.5 | 0.028* | 1.9 | 40.0 |
| | | | SHAM | 23.8* | 7.5 | 0.011* | 4.7 | 42.8 |
| | | KT | SHAM | 2.8 | 7.5 | 1 | -16.2 | 21.9 |
| | 3 | CON | KT | 17.7 | 8.3 | 0.122 | -3.3 | 38.7 |
| | | | SHAM | 19.1 | 8.3 | 0.085 | -1.9 | 40.1 |
| | | KT | SHAM | 1.4 | 8.3 | 1 | -19.6 | 22.4 |
| Symptom | 0 | CON | KT | 27.6* | 6.8 | 0.001* | 10.4 | 44.8 |
| | | | SHAM | 24.7* | 6.8 | 0.003* | 7.4 | 41.9 |
| | | KT | SHAM | -2.9 | 6.8 | 1 | -20.2 | 14.3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 | CON | KT | 25.7* | 7.3 | 0.004 | 7.1 | 44.2 |
| | | | SHAM | 23.1* | 7.3 | 0.011* | 4.5 | 41.6 |
| | | KT | SHAM | -2.6 | 7.3 | 1 | -21.2 | 16.0 |

* The mean difference is significant at the .05 level; 0: baseline time point; 3: 3 days post-tape removal.

Table 11 Pairwise Comparisons of Rest Four KOOS Variables Between Two Time points Within Each Group

| Measure | GROUP | (I) Time | (J) Time | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| ADL | CON | 0 | 3 | 1 | -4.5 | 4.5 |
| | KT | 0 | 3 | 0.394 | -6.4 | 2.6 |
| | SHAM | 0 | 3 | 0.08 | -8.5 | 0.5 |
| QOL | CON | 0 | 3 | 1 | -9.2 | 9.2 |
| | KT | 0 | 3 | 0.175 | -15.4 | 2.9 |
| | SHAM | 0 | 3 | 0.14 | -16.0 | 2.4 |
| Sport/ Rec | CON | 0 | 3 | 1 | -9.6 | 9.6 |
| | KT | 0 | 3 | 0.504 | -12.8 | 6.4 |
| | SHAM | 0 | 3 | 0.329 | -14.3 | 4.9 |
| Symptom | CON | 0 | 3 | 0.723 | -6.5 | 4.6 |
| | KT | 0 | 3 | 0.292 | -8.5 | 2.6 |
| | SHAM | 0 | 3 | 0.348 | -8.2 | 3.0 |

Based on estimated marginal means; 0: baseline time point; 3: 3 days post-tape removal.

Table 12 The Time, Group, and Interaction Effects of Each Gait Variable

| Outcomes | CON | KT | SHAM | F | Group (Sig.) | F | Time (Sig.) | F | Interaction (Sig.) |
|---|---|---|---|---|---|---|---|---|---|
| Walking Velocity (m/s) | 1.3(0.06) | 1.1(0.06) | 1.2(0.06) | 1.74 | 0.193 | 5.43 | 0.002* | 1.22 | 0.302 |
| GRF (N) | 792.4(49.8) | 716.4(52.3) | 771.3(49.8) | 0.59 | 0.564 | 0.43 | 0.72 | 1.10 | 0.37 |
| Loading Rate (N/s) | 3891.5(603.9) | 3119.9(633.4) | 3862.2(603.9) | 0.49 | 0.617 | 1.31 | 0.276 | 2.24 | 0.052* |
| PKFA (°) | 49.6(1.5) | 48.3(1.6) | 48.0(1.5) | 0.32 | 0.731 | 1.07 | 0.368 | 2.53 | 0.026* |
| KFA at IC (°) | 10.8(1.6) | 11.5(1.7) | 11.5(1.6) | 0.06 | 0.939 | 1.22 | 0.306 | 150 | 0.197 |
| PKAA (°) | 5.1(1.2) | 4.0(1.2) | 3.9(1.2) | 0.32 | 0.726 | 1.76 | 0.16 | 3.49 | 0.004* |
| PKFM (N*m) | 0.8(0.07) | 0.7(0.07) | 0.7(0.07) | 1.20 | 0.315 | 0.27 | 0.784 | 1.21 | 0.318 |
| PKAM (N*m) | 0.5(0.04) | 0.5(0.04) | 0.5(0.04) | 0.23 | 0.799 | 0.66 | 0.58 | 0.80 | 0.569 |

* The mean difference is significant at the .05 level

Table 13 The Repeated ANOVA Results of Loading Rate, PKFA, and PKAA Within Each Group

| | CON | | KT | | SHAM | |
|---|---|---|---|---|---|---|
| Outcomes | F | Sig | F | Sig | F | Sig |
| Loading Rate (N/s) | 3.065 | 0.043* | 1.166 | 0.341 | 0.66 | 0.531 |
| PKFA (°) | 1.8 | 0.169 | 3.132 | 0.042* | 2.959 | 0.048* |
| PKAA (°) | 1.203 | 0.326 | 3.863 | 0.02* | 1.718 | 0.185 |

The mean difference is significant at the .05 level.

Table 14 The Pairwise Comparisons of Time Difference for Loading Rate, PKAA, and PKFA in Each Group

| Outcomes | (I) time | (J) time | CON | | | KT | | | SHAM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 95% CI | | Sig. | 95% CI | | Sig. | 95% CI | | Sig. |
| | | | Lower Bound | Upper Bound | | Lower Bound | Upper Bound | | Lower Bound | Upper Bound | |
| Loading Rate (N/s) | 0 | 1 | -890.4 | 495.4 | 0.54 | -1201 | 796.3 | 0.658 | -640.5 | 353.8 | 0.535 |
| | | 2 | -1449 | -254.8 | 0.01* | -320.9 | 425.5 | 0.758 | -525.5 | 236.2 | 0.417 |
| | | 3 | -945.6 | 966.2 | 0.981 | -1346.4 | 243.7 | 0.151 | -694.2 | 233.6 | 0.295 |
| | 1 | 2 | -1358 | 49.7 | 0.065 | -739.6 | 1248.9 | 0.577 | -242.3 | 239.6 | 0.991 |
| | | 3 | -488.4 | 904.1 | 0.521 | -1203.3 | 505.3 | 0.38 | -291.2 | 117.3 | 0.365 |
| | 2 | 3 | 173.2 | 1550.8 | 0.019* | -1280.8 | 73.5 | 0.075 | -426.5 | 255.2 | 0.588 |
| PKFA (°) | 0 | 1 | -1.0 | 3.5 | 0.243 | 1.0 | 6.5 | 0.015* | -0.6 | 3.0 | 0.157 |
| | | 2 | -3.1 | 1.1 | 0.324 | 0.4 | 7.3 | 0.031* | -1.6 | 1.6 | 0.995 |
| | | 3 | -2.1 | 1.6 | 0.754 | -1.7 | 7.4 | 0.188 | -4.2 | 1.3 | 0.27 |
| | 1 | 2 | -4.8 | 0.4 | 0.085 | -2.6 | 2.8 | 0.91 | -2.7 | 0.3 | 0.104 |
| | | 3 | 4.0 | 0.9 | 0.196 | -4.0 | 2.3 | 0.549 | -4.2 | -1.1 | 0.003* |
| | 2 | 3 | -1.0 | 2.4 | 0.376 | -3.5 | 1.5 | 0.385 | -3.9 | 1.0 | 0.212 |
| PKAA (°) | 0 | 1 | -0.3 | 4.6 | 0.078 | -3.1 | 3.4 | 0.901 | -5.3 | 2.0 | 0.337 |
| | | 2 | -2.9 | 3.7 | 0.783 | -2.7 | 2.5 | 0.956 | -5.0 | -0.6 | 0.016* |
| | | 3 | -1.4 | 5.2 | 0.233 | 0.6 | 5.6 | 0.022* | -6.6 | 1.5 | 0.186 |
| | 1 | 2 | -4.2 | 0.8 | 0.151 | -2.1 | 1.6 | 0.77 | -4.0 | 1.7 | 0.381 |
| | | 3 | -3.0 | 2.5 | 0.833 | 0.5 | 5.2 | 0.021* | -3.5 | 1.6 | 0.422 |
| | 2 | 3 | -2.4 | 5.3 | 0.416 | 1.2 | 5.0 | 0.005* | -26 | 3.0 | 0.866 |

95% CI: 95% Confidence Interval for Difference; * The mean difference is significant at the .05 level; The pairwise comparisons of Repeated Measures ANOVA for each group; 0: baseline time point; 1: immediate post-tape; 2: 3 days post-tape; 3: 3 days post-tape removal.

Table 15 Pairwise Comparisons of Gait Variables for Time Difference Within Each Group

| Outcomes | GROUP | (I) Time | (J) Time | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval for Difference | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Walking Velocity (m/s) | CON | 0 | 1 | -0.04 | 0.029 | 0.808 | -0.128 | 0.038 |
| | | | 2 | -.089* | 0.027 | 0.014* | -0.164 | -0.014 |
| | | | 3 | -.093* | 0.029 | 0.018* | -0.174 | -0.012 |
| | | 1 | 2 | -0.04 | 0.024 | 0.495 | -0.113 | 0.025 |
| | | | 3 | -0.047 | 0.024 | 0.318 | -0.114 | 0.019 |
| | | 2 | 3 | -0.004 | 0.02 | 1 | -0.059 | 0.052 |
| | KT | 0 | 1 | -0.011 | 0.031 | 1 | -0.098 | 0.077 |
| | | | 2 | -0.036 | 0.028 | 1 | -0.115 | 0.044 |
| | | | 3 | -0.042 | 0.03 | 1 | -0.126 | 0.043 |
| | | 1 | 2 | -0.025 | 0.026 | 1 | -0.097 | 0.047 |
| | | | 3 | -0.031 | 0.025 | 1 | -0.101 | 0.039 |
| | | 2 | 3 | -0.006 | 0.021 | 1 | -0.064 | 0.052 |
| | SHAM | 0 | 1 | -0.035 | 0.029 | 1 | -0.119 | 0.048 |
| | | | 2 | -0.01 | 0.027 | 1 | -0.085 | 0.065 |
| | | | 3 | -0.038 | 0.029 | 1 | -0.119 | 0.043 |
| | | 1 | 2 | 0.025 | 0.024 | 1 | -0.044 | 0.094 |
| | | | 3 | -0.003 | 0.024 | 1 | -0.069 | 0.064 |
| | | 2 | 3 | -0.028 | 0.02 | 0.99 | -0.084 | 0.028 |
| GRF (N) | CON | 0 | 1 | -16.448 | 5.954 | 0.059 | -33.308 | 0.411 |
| | | | 2 | -16.59 | 8.389 | 0.345 | -40.344 | 7.165 |
| | | | 3 | -14.537 | 9.547 | 0.832 | -41.57 | 12.495 |
| | | 1 | 2 | -0.141 | 7.886 | 1 | -22.471 | 22.189 |
| | | | 3 | 1.911 | 7.196 | 1 | -18.464 | 22.285 |
| | | 2 | 3 | 2.052 | 7.602 | 1 | -19.473 | 23.577 |
| | KT | 0 | 1 | -1.387 | 6.245 | 1 | -19.069 | 16.296 |
| | | | 2 | -2.437 | 8.799 | 1 | -27.351 | 22.477 |
| | | | 3 | -6.03 | 10.013 | 1 | -34.382 | 22.322 |
| | | 1 | 2 | -1.051 | 8.271 | 1 | -24.471 | 22.369 |
| | | | 3 | -4.643 | 7.547 | 1 | -26.012 | 16.726 |
| | | 2 | 3 | -3.593 | 7.973 | 1 | -26.168 | 18.983 |
| | SHAM | 0 | 1 | 6.954 | 5.954 | 1 | -9.906 | 23.813 |
| | | | 2 | 6.717 | 8.389 | 1 | -17.037 | 30.472 |
| | | | 3 | 6.196 | 9.547 | 1 | -20.837 | 33.228 |
| | | 1 | 2 | -0.236 | 7.886 | 1 | -22.566 | 22.094 |
| | | | 3 | -0.758 | 7.196 | 1 | -21.133 | 19.616 |
| | | 2 | 3 | -0.522 | 7.602 | 1 | -22.047 | 21.003 |
| Loading Rate (N/s) | CON | 0 | 1 | -197.526 | 324.801 | 1 | -1117.217 | 722.165 |
| | | | 2 | -851.671* | 206.148 | 0.002* | -1435.389 | -267.953 |
| | | | 3 | 10.345 | 336.541 | 1 | -942.587 | 963.277 |
| | | 1 | 2 | -654.145 | 304.863 | 0.242 | -1517.381 | 209.092 |
| | | | 3 | 207.871 | 277.142 | 1 | -576.872 | 992.614 |
| | | 2 | 3 | 862.016* | 257.496 | 0.014* | 132.903 | 1591.128 |
| | KT | 0 | 1 | -202.339 | 340.654 | 1 | -1166.919 | 762.241 |
| | | | 2 | 52.315 | 216.209 | 1 | -559.893 | 664.523 |
| | | | 3 | -551.329 | 352.967 | 0.775 | -1550.773 | 448.115 |
| | | 1 | 2 | 254.654 | 319.743 | 1 | -650.716 | 1160.024 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 3 | -348.99 | 290.669 | 1 | -1172.036 | 474.055 |
| | | 2 | 3 | -603.644 | 270.064 | 0.2 | -1368.344 | 161.055 |
| | | | 1 | -143.353 | 324.801 | 1 | -1063.044 | 776.338 |
| | | | 2 | -144.671 | 206.148 | 1 | -728.389 | 439.047 |
| | SHAM | | | | | | | |
| | | 0 | 3 | -230.311 | 336.541 | 1 | -1183.244 | 722.621 |
| | | | 2 | -1.318 | 304.863 | 1 | -864.554 | 861.919 |
| | | 1 | 3 | -86.958 | 277.142 | 1 | -871.701 | 697.785 |
| | | 2 | 3 | -85.64 | 257.496 | 1 | -814.753 | 643.472 |
| | | | 1 | 2.148 | 1.325 | 0.694 | -1.602 | 5.899 |
| | | | 2 | 0.412 | 1.305 | 1 | -3.283 | 4.106 |
| | CON | 0 | 3 | 1.88 | 1.745 | 1 | -3.061 | 6.821 |
| | | | 2 | -1.737 | 1.176 | 0.904 | -5.067 | 1.594 |
| | | 1 | 3 | -0.268 | 1.226 | 1 | -3.739 | 3.203 |
| | | 2 | 3 | 1.468 | 1.378 | 1 | -2.434 | 5.37 |
| | | | 1 | 3.728 | 1.389 | 0.071 | -0.206 | 7.662 |
| | | | 2 | 3.867 | 1.368 | 0.051* | -0.007 | 7.742 |
| PKFA (°) | KT | 0 | 3 | 2.872 | 1.83 | 0.764 | -2.31 | 8.055 |
| | | | 2 | 0.139 | 1.234 | 1 | -3.354 | 3.632 |
| | | 1 | 3 | -0.856 | 1.286 | 1 | -4.496 | 2.785 |
| | | 2 | 3 | -0.995 | 1.445 | 1 | -5.087 | 3.098 |
| | | | 1 | -1.635 | 1.325 | 1 | -5.386 | 2.116 |
| | | | 2 | -2.795 | 1.305 | 0.244 | -6.489 | 0.9 |
| | SHAM | 0 | 3 | -2.579 | 1.745 | 0.901 | -7.52 | 2.362 |
| | | | 2 | -1.16 | 1.176 | 1 | -4.49 | 2.171 |
| | | 1 | 3 | -0.944 | 1.226 | 1 | -4.415 | 2.527 |
| | | 2 | 3 | 0.216 | 1.378 | 1 | -3.686 | 4.117 |
| | | | 1 | 0.842 | 1.357 | 1 | -3.001 | 4.685 |
| | | | 2 | -0.4 | 1.086 | 1 | -3.475 | 2.675 |
| | CON | 0 | 3 | 2.339 | 1.747 | 1 | -2.608 | 7.285 |
| | | | 2 | -1.242 | 1.115 | 1 | -4.399 | 1.915 |
| | | 1 | 3 | 1.497 | 1.242 | 1 | -2.021 | 5.014 |
| | | 2 | 3 | 2.739 | 1.506 | 0.476 | -1.525 | 7.002 |
| | | | 1 | 2.801 | 1.423 | 0.352 | -1.229 | 6.831 |
| | | | 2 | 3.198 | 1.139 | 0.053* | -0.027 | 6.423 |
| KFA at IC (°) | KT | 0 | 3 | 2.216 | 1.832 | 1 | -2.972 | 7.404 |
| | | | 2 | 0.397 | 1.169 | 1 | -2.914 | 3.708 |
| | | 1 | 3 | -0.585 | 1.303 | 1 | -4.274 | 3.104 |
| | | 2 | 3 | -0.982 | 1.579 | 1 | -5.453 | 3.489 |
| | | | 1 | -0.275 | 1.357 | 1 | -4.118 | 3.567 |
| | | | 2 | -1.734 | 1.086 | 0.726 | -4.809 | 1.34 |
| | SHAM | 0 | 3 | -0.595 | 1.747 | 1 | -5.542 | 4.352 |
| | | | 2 | -1.459 | 1.115 | 1 | -4.616 | 1.698 |
| | | 1 | 3 | -0.32 | 1.242 | 1 | -3.837 | 3.198 |
| | | 2 | 3 | 1.139 | 1.506 | 1 | -3.124 | 5.403 |
| | | | 1 | 1.243 | 1.069 | 1 | -1.784 | 4.27 |
| | | | 2 | -0.984 | 0.923 | 1 | -3.599 | 1.631 |
| | CON | 0 | 3 | -0.271 | 1.053 | 1 | -3.254 | 2.712 |
| | | | 2 | -2.227 | 0.903 | 0.119 | -4.784 | 0.33 |
| PKAA (°) | | 1 | 3 | -1.514 | 0.937 | 0.7 | -4.166 | 1.138 |
| | | 2 | 3 | 0.713 | 0.897 | 1 | -1.827 | 3.253 |
| | | | 1 | 0.185 | 1.121 | 1 | -2.99 | 3.359 |
| | KT | 0 | 2 | -0.066 | 0.969 | 1 | -2.808 | 2.677 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 3 | 3.048 | 1.105 | 0.06 | -0.081 | 6.176 |
| | | | 2 | -0.25 | 0.947 | 1 | -2.932 | 2.431 |
| | | 1 | 3 | 2.863* | 0.982 | 0.041* | 0.082 | 5.644 |
| | | 2 | 3 | 3.113* | 0.941 | 0.015* | 0.449 | 5.777 |
| | | | 1 | 1.2 | 1.069 | 1 | -1.827 | 4.227 |
| | | | 2 | 0.005 | 0.923 | 1 | -2.61 | 2.62 |
| | SHAM | 0 | 3 | -1.438 | 1.053 | 1 | -4.42 | 1.545 |
| | | | 2 | -1.195 | 0.903 | 1 | -3.752 | 1.362 |
| | | 1 | 3 | -2.638 | 0.937 | 0.052* | -5.29 | 0.014 |
| | | 2 | 3 | -1.443 | 0.897 | 0.712 | -3.983 | 1.098 |
| | | | 1 | -0.076 | 0.051 | 0.888 | -0.221 | 0.069 |
| | | | 2 | -0.112 | 0.049 | 0.168 | -0.25 | 0.025 |
| | CON | 0 | 3 | -0.046 | 0.083 | 1 | -0.281 | 0.188 |
| | | | 2 | -0.036 | 0.035 | 1 | -0.137 | 0.064 |
| | | 1 | 3 | 0.03 | 0.076 | 1 | -0.186 | 0.245 |
| | | 2 | 3 | 0.066 | 0.08 | 1 | -0.162 | 0.294 |
| | | | 1 | 0.1 | 0.054 | 0.445 | -0.053 | 0.252 |
| | | | 2 | 0.099 | 0.051 | 0.373 | -0.045 | 0.243 |
| PKFM (N*m) | KT | 0 | 3 | 0.014 | 0.087 | 1 | -0.232 | 0.259 |
| | | | 2 | -0.001 | 0.037 | 1 | -0.106 | 0.105 |
| | | 1 | 3 | -0.086 | 0.08 | 1 | -0.312 | 0.14 |
| | | 2 | 3 | -0.085 | 0.084 | 1 | -0.324 | 0.153 |
| | | | 1 | -0.053 | 0.051 | 1 | -0.198 | 0.092 |
| | | | 2 | -0.06 | 0.049 | 1 | -0.197 | 0.078 |
| | SHAM | 0 | 3 | -0.061 | 0.083 | 1 | -0.295 | 0.173 |
| | | | 2 | -0.006 | 0.035 | 1 | -0.107 | 0.094 |
| | | 1 | 3 | -0.008 | 0.076 | 1 | -0.223 | 0.207 |
| | | 2 | 3 | -0.001 | 0.08 | 1 | -0.229 | 0.226 |
| | | | 1 | 0.031 | 0.022 | 1 | -0.032 | 0.094 |
| | | | 2 | -0.012 | 0.022 | 1 | -0.075 | 0.051 |
| | CON | 0 | 3 | -0.003 | 0.021 | 1 | -0.063 | 0.058 |
| | | | 2 | -0.043 | 0.026 | 0.647 | -0.117 | 0.031 |
| | | 1 | 3 | -0.034 | 0.023 | 0.899 | -0.098 | 0.031 |
| | | 2 | 3 | 0.01 | 0.029 | 1 | -0.073 | 0.092 |
| | | | 1 | 0.01 | 0.023 | 1 | -0.056 | 0.076 |
| | | | 2 | 0.002 | 0.023 | 1 | -0.064 | 0.068 |
| PKAM (N*m) | KT | 0 | 3 | 0.021 | 0.022 | 1 | -0.042 | 0.084 |
| | | | 2 | -0.008 | 0.027 | 1 | -0.086 | 0.069 |
| | | 1 | 3 | 0.011 | 0.024 | 1 | -0.057 | 0.079 |
| | | 2 | 3 | 0.019 | 0.031 | 1 | -0.068 | 0.106 |
| | | | 1 | -0.018 | 0.022 | 1 | -0.081 | 0.045 |
| | | | 2 | -0.023 | 0.022 | 1 | -0.086 | 0.04 |
| | SHAM | 0 | 3 | -0.037 | 0.021 | 0.547 | -0.098 | 0.023 |
| | | | 2 | -0.005 | 0.026 | 1 | -0.079 | 0.069 |
| | | 1 | 3 | -0.019 | 0.023 | 1 | -0.084 | 0.045 |
| | | 2 | 3 | -0.014 | 0.029 | 1 | -0.097 | 0.068 |

Based on estimated marginal means; * The mean difference is significant at the .05 level; 0: baseline time point; 1: immediate post-tape; 2: 3 days post-tape; 3: 3 days post-tape removal.

## Appendix B: Consent forms for Knee pain and control participants

**RESEARCH SUBJECT INFORMATION AND CONSENT FORM**

**TITLE:** The Effects of Kinesio Tape™ on Proprioception, Balance, and Gait in Individuals With Symptomatic and Asymptomatic Knee Pain

**PROTOCOL NO.:** 2019-00287

**PRIMARY INVESTIGATOR:**
Kaori Tamura, PhD, ATC
1337 Lower Campus Rd
Honolulu, Hawaii 96822
United States

**STUDENT INVESTIGATOR:**
Adriana Trost, BS, ATC & Jingyu Hu, BS
1337 Lower Campus Rd
Honolulu, Hawaii 96822
United States

**SITE(S):**
University of Hawaii at Manoa
Biomechanics and Gait Laboratory
Stan Sheriff Center Room 100
Honolulu, Hawaii 96822
United States

**STUDY-RELATED PHONE NUMBER(S):**
Adriana Trost, BS, ATC
303-457-3332

Jingyu Hu, BS
812-391-0594

Kaori Tamura, PhD, ATC
808-956-3801

This consent form may contain words that you do not understand. Please ask the study doctor or the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

**SUMMARY**

You are being asked to be a participant in a research pilot study. The purpose of this consent form is to help you decide if you want to be in the research study. Please read this consent

form carefully. To be in a research study you must give your informed consent. "Informed consent" includes:

- Reading this consent form
- Receiving a thorough explanation of the research study from study staff
- Asking questions about anything that is not clear, and
- Taking home an unsigned copy of this consent form. This gives you time to think about it and to talk to family or friends before you make your decision.

You should not join this research study until all of your questions are answered.

Things to know before deciding to take part in a research study:

- The main goal of a research study is to learn in order to help individuals in the future.
- The main goal of regular medical care is to help each individual.
- No one can promise that a research study will help you.
- Taking part in a research study is entirely voluntary. No one can make you take part.
- If you decide to take part, you can change your mind later on and withdraw from the research study at any time.
- The decision to join or not join the research study will not cause you to lose any medical benefits. If you decide not to take part in this study, your doctor will continue to treat you.
- Parts of this study may involve standard medical care. Standard care is the treatment normally given for a certain condition or illness.
- After reading the consent form and having a discussion with the research staff, you should know which parts of the study are experimental (investigational) and which are standard medical care.
- Your medical records may become part of the research record. If that happens, your medical records may be looked at and/or copied by the sponsor of this study and government agencies or other groups associated with the study.

After reading and discussing the information in this consent form you should know:

- Why this research study is being done;
- What will happen during the research;
- Any possible benefits to you;
- The possible risks to you;
- How problems will be treated during the study and after the study is over.

If you take part in this research study, you will be given a copy of this signed and dated consent form.

**PURPOSE OF THE STUDY**

The purpose of this study is to compare the effects of Kinesio Tape™ on: 1) proprioception examined through joint position sense tests, 2) balance ability through completion of a series of balance tests, 3) gait and 4) the individuals' perceived pain and limitations as obtained through a survey.

**RESEARCH SUBJECT CRITERIA**

Test subjects will meet one or more of the following criteria:

- Pain with rest in the affected knee(s)

- Pain with normal movements/activities of daily living
- Pain and/or limitations with going up and down stairs
- And/or stiffness in your affected knee(s)

Exclusion criteria include:
- Current lower limb injury
- Currently a candidate for knee replacement surgery
- Open wounds around knee or thigh area
- Require assistance during walking
- Skin sensitivity to tape
- Any neurological conditions
- Current back pain
- Rheumatoid arthritis of the lower body
- Unable to sit with feet flat on ground
- And/or unable to fully extend the knee

**PROCEDURES**

If you decide to participate in this study, you will be asked to report to the University of Hawaii at Manoa, Kinesiology and Rehabilitation Science Laboratory (Biomechanics and Gait Lab, Stan Sheriff 100) for four data collection sessions.

Upon arrival to the Biomechanics and Gait Lab, you will be asked to fill out one brief survey in reference to your current health and function. When you arrive at the Biomechanics and Gait Lab, measurements about your height and body weight will be taken, as well as a measurement of your thigh length. After 31 reflective markers are placed on your legs, hips, and upper body, you will be asked to perform the following tasks, in the specified order:

(1) A standing calibration of the motion capture system, followed by three (3) successful walking trials, per leg, at a self-selected pace.

(2) A familiarization trial, followed by ten (10) single leg, seated knee extension repetitions to the test angle of 30 degrees of knee flexion, to be completed on each limb (total of 10 knee extension repetitions per limb). Each repetition will be held for 3 seconds prior to returning to the starting position.

(3) Completion of a series of balance ability tests, where you will be asked to perform tasks similar to those done in everyday life such as picking up something from the ground, balancing on two feet, and transferring yourself from one chair to another.

(4) A familiarization trial followed by ten (10) double leg squat repetitions to the test angle of 30 degrees of knee flexion. Each repetition will be held for 3 seconds prior to returning to the starting position.

Prior to Kinesio Tape™ application, you may be asked to shave the front of your thigh to which the Kinesio Tape™ is being applied.

The entire visit will take approximately 60 minutes.

**RISKS AND DISCOMFORTS**

There are minimal risks associated with your participation in this study. These include but are not limited to:

- Soreness and/or pain during and/or after participation
- Lower leg injury
- Stiffness after participation
- Falling during balance tests and walking examination

Due to the level of physical activity involved, there is a risk of injury. You may have pain in your legs during testing. You may also have some fatigue, discomfort, muscle cramping or soreness during or after the test sessions. Although we have people to assist you and a chair for balance in place, there is a chance of falling during the test. There is a very remote chance of a medical emergency such as: cardiac arrest, stroke, and/or death. These risks are comparable to your activities of daily living.

**NEW INFORMATION**

You will be told about anything new that might change your decision to be in this study. You may be asked to sign a revised consent form if this occurs.

**BENEFITS**

You may not receive direct/immediate benefits. However, you may obtain information regarding your joint position sense tests, as well as information for the biomechanics of walking and balancing tests. Results of this study may assist physicians, physical therapists, strength and conditioning specialists, and athletic trainers to ensure the optimal clinical outcomes when considering the effects of Kinesio Tape™ on joint position sense, balance, and walking mechanics.

**PAYMENT FOR PARTICIPATION**

There is no compensation provided for your participation in this four-time data collection. No medical insurance is collected. There is no charge to your insurance company for your participation in this study.

**COSTS**

There are no additional costs related to the procedures and visit. Any costs for transportation to/from the UH Biomechanics and Gait Lab are your responsibility.

**ALTERNATIVE TREATMENT**

Your alternative is not to participate in this study. There is no treatment associated with this study beyond the potentially beneficial effect of Kinesio Tape™.

**USE AND DISCLOSURE OF YOUR HEALTH INFORMATION:**

By signing this form, you are authorizing the use and disclosure of individually identifiable information. Your information will only be used/disclosed as described in this consent form and as permitted by state and federal laws. If you refuse to give permission, you will not be able to be in this research.

This consent covers all information about you that is used or collected for this study. It includes

- Research records
- Records about your study visit
- Self-reported medical questionnaire documentation

Your authorization to use your identifiable health information will not expire even if you terminate your participation in this study or you are removed from this study by the study staff. However, you may revoke your authorization to use your identifiable information at any time by submitting a written notification to the principal investigator, Dr. Kaori Tamura, University of Hawaii at Manoa, Honolulu, HI 96822. If you decide to revoke (withdraw or "take back") your authorization, your identifiable health information collected or created for this study shall not be used or disclosed by the study staff after the date of receipt of the written revocation except to the extent that the law allows us to continue using your information. The investigators in this study are not required to destroy or retrieve any of your health information that was created, used or disclosed for this study prior to receiving your written revocation.

By signing this consent form you authorize the following parties to use and or disclose your identifiable health information collected or created for this study:

- Kaori Tamura and her research staff for the purposes of conducting this research study.
- University of Hawaii at Manoa.

The individuals named above may disclose this consent form and the information about you created by this study to:

- The sponsor of this study and their designees (if applicable)
- Federal, state and local agencies having oversight over this research, such as the Office for Human Research Protections in the U.S. Department of Health and Human Services, Food and Drug Administration, the National Institutes of Health, etc.
- The University of Hawai‘i for purposes of overseeing the research study and making sure that your ethical rights are being protected.

Some of the persons or groups that receive your study information may not be required to comply with federal privacy regulations, and your information may lose its federal privacy protection and your information may be disclosed without your permission

**COMPENSATION FOR INJURY**

In the event of any physical injury from the research, only immediate and essential medical treatment is available. First Aid/CPR and a referral to a medical emergency room will be provided. In the event of any emergency incidence outside the lab as a result of this research, contact your medical doctor and inform the study coordinator: Kaori Tamura Ph.D., ATC, at 808-956-3801. You should understand that if you are injured in the course of this research process that you or your medical insurance will be billed for the costs of treating your injuries.

**VOLUNTARY PARTICIPATION AND WITHDRAWAL**

Your participation in this study is voluntary. You may decide not to participate or you may leave the study at any time. Your decision will not result in any penalty or loss of benefits to which you are entitled.

Your participation in this study may be stopped at any time by the study doctor or the sponsor without your consent for any of the following reasons:

- it is in your best interest;
- you do not consent to continue in the study after being told of changes in the research that may affect you;
- you become pregnant;
- or for any other reason.

If you leave the study before the planned final visit, you may be asked by the study doctor to have some of the end of study procedures done.

**SOURCE OF FUNDING FOR THE STUDY**

This research study is sponsored by the University of Hawaii, Manoa.

**QUESTIONS**

Contact Kaori Tamura, Ph.D., ATC at 808-956-3801, Adriana Trost, BS, ATC at 303-457-3332, or Jingyu Hu, BS at (812)-391-0594 for any of the following reasons:

- if you have any questions about this study or your part in it
- if you feel you have had a research-related injury or
- if you have questions, concerns or complaints about the research

You may contact the UH Human Studies Program at (808) 956-5007 or uhirb@hawaii.edu. to discuss problems, concerns and questions; obtain information; or offer input with an informed individual who is unaffiliated with the specific research protocol. Please visit http://go.hawaii.edu/jRd for more information on your rights as a research participant.

The Human Studies Program will not be able to answer some study-specific questions, such as questions about appointment times. However, you may contact them if the research staff cannot be reached or if you wish to talk to someone other than the research staff.

Do not sign this consent form unless you have had a chance to ask questions and have gotten satisfactory answers.

If you agree to be in this study, you will receive a signed and dated copy of this consent form for your records.

**CONSENT**

I have read this consent form. All my questions about the study and my part in it have been answered. I freely consent to be in this research study.

I authorize the use and disclosure of my health information to the parties listed in the authorization section of this consent for the purposes described above.

By signing this consent form, I have not given up any of my legal rights.

_____

Subject Name (printed)

**CONSENT SIGNATURE:**

_____

_____

Signature of Subject Date

_____

_____

Signature of Person Conducting Informed Consent Discussion Date

**RESEARCH SUBJECT INFORMATION AND CONSENT FORM**
**FOR CONTROL GROUP**

**TITLE:** The Effects of Kinesio Tape™ on Proprioception, Balance, and Gait in Individuals With Symptomatic and Asymptomatic Knee Pain

**PROTOCOL NO.:** 2019-00287

**PRIMARY INVESTIGATOR:**
Kaori Tamura, PhD, ATC
1337 Lower Campus Rd
Honolulu, Hawaii 96822
United States

**STUDENT INVESTIGATOR:**
Adriana Trost, BS, ATC & Jingyu Hu, BS
1337 Lower Campus Rd
Honolulu, Hawaii 96822
United States

**SITE(S):**
University of Hawaii at Manoa
Biomechanics and Gait Laboratory
Stan Sheriff Center Room 100
Honolulu, Hawaii 96822
United States

**STUDY-RELATED PHONE NUMBER(S):**
Adriana Trost, BS, ATC
303-457-3332

Jingyu Hu, BS
812-391-0594

Kaori Tamura, PhD, ATC
808-956-3801

This consent form may contain words that you do not understand. Please ask the study doctor or the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

**SUMMARY**

You are being asked to be a participant in a research pilot study. The purpose of this consent form is to help you decide if you want to be in the research study. Please read this consent

form carefully. To be in a research study you must give your informed consent. "Informed consent" includes:

- Reading this consent form
- Receiving a thorough explanation of the research study from study staff
- Asking questions about anything that is not clear, and
- Taking home an unsigned copy of this consent form. This gives you time to think about it and to talk to family or friends before you make your decision.

You should not join this research study until all of your questions are answered.

Things to know before deciding to take part in a research study:

- The main goal of a research study is to learn in order to help individuals in the future.
- The main goal of regular medical care is to help each individual.
- No one can promise that a research study will help you.
- Taking part in a research study is entirely voluntary. No one can make you take part.
- If you decide to take part, you can change your mind later on and withdraw from the research study at any time.
- The decision to join or not join the research study will not cause you to lose any medical benefits. If you decide not to take part in this study, your doctor will continue to treat you.
- Parts of this study may involve standard medical care. Standard care is the treatment normally given for a certain condition or illness.
- After reading the consent form and having a discussion with the research staff, you should know which parts of the study are experimental (investigational) and which are standard medical care.
- Your medical records may become part of the research record. If that happens, your medical records may be looked at and/or copied by the sponsor of this study and government agencies or other groups associated with the study.

After reading and discussing the information in this consent form you should know:

- Why this research study is being done;
- What will happen during the research;
- Any possible benefits to you;
- The possible risks to you;
- How problems will be treated during the study and after the study is over.

If you take part in this research study, you will be given a copy of this signed and dated consent form.

**PURPOSE OF THE STUDY**

The purpose of this study is to compare the effects of Kinesio Tape™ on: 1) proprioception examined through joint position sense tests, 2) balance ability through completion of series of balance tests, 3) gait and 4) the patients' perceived pain and limitations as obtained through a survey.

**RESEARCH SUBJECT CRITERIA**

Exclusion criteria include:

- Pain with rest in the affected knee(s)

- Pain with normal movements/activities of daily living
- Pain and/or limitations with going up and down stairs
- And/or stiffness in your affected knee(s)

**PROCEDURES**

If you decide to participate in this study, you will be asked to report to the University of Hawaii at Manoa, Kinesiology and Rehabilitation Science Laboratory (Biomechanics and Gait Lab, Stan Sheriff 100) for four data collection sessions.

Upon arrival to the Biomechanics and Gait Lab, you will be asked to fill out one brief survey in reference to your current health and function. When you arrive at the Biomechanics and Gait Lab, measurements about your height and body weight will be taken, as well as a measurement of your thigh length. After 31 reflective markers are placed on your legs, hips, and upper body, you will be asked to perform the following tasks, in the specified order:

(1) A standing calibration of the motion capture system, followed by three (3) successful walking trials, per leg, at a self-selected pace.

(2) A familiarization trial followed by ten (10) single leg, seated knee extension repetitions to the test angle of 30 degrees of knee flexion, to be completed on each limb (total of 10 knee extension repetitions per leg). Each repetition will be held for 3 seconds prior to returning to the starting position

(3) Completion of a series of balance ability tests, where you will be asked to perform tasks similar to those done in everyday life such as picking up something from the ground, balancing on two feet, and transferring yourself from one chair to another.

(4) A familiarization trial followed by ten (10) double leg squat repetitions to the test angle of 30 degrees of knee flexion. Each repetition will be held for 3 seconds prior to returning to the starting position

Prior to Kinesio Tape™ application, you may be asked to shave the front of your thigh to which the Kinesio Tape™ is being applied.

The entire visit will take approximately 60 minutes.

**RISKS AND DISCOMFORTS**

There are minimal risks associated with your participation in this study. These include but are not limited to:

- Soreness and/or pain during and/or after participation
- Lower leg injury
- Stiffness after participation
- Falling during balance tests and walking examination

Due to the level of physical activity involved, there is a risk of injury. You may have pain in your legs during testing. You may also have some fatigue, discomfort, muscle cramping or soreness during or after test sessions. Although we have people to assist you and a chair for

balance in place, there is a chance of falling during the test. There is a very remote chance of a medical emergencies such as: cardiac arrest, stroke, and/or death. These risks are comparable to your activities of daily living.

**NEW INFORMATION**

You will be told about anything new that might change your decision to be in this study. You may be asked to sign a revised consent form if this occurs.

**BENEFITS**

You may not receive direct/immediate benefits. However, you may obtain information regarding your joint position sense tests, as well as information for the biomechanics of walking and the balancing tests. Results of this study may assist physicians, physical therapists, strength and conditioning specialists, and athletic trainers to ensure the optimal clinical outcomes when considering the effects of Kinesio Tape™ on joint position sense, balance, and walking mechanics.

**PAYMENT FOR PARTICIPATION**

There is no compensation provided for your participation in this four-time data collection. No medical insurance is collected. There is no charge to your insurance company for your participation in this study.

**COSTS**

There are no additional costs related to the procedures and visit. Any costs for transportation to/from the UH Biomechanics and Gait Lab are your responsibility.

**ALTERNATIVE TREATMENT**

Your alternative is not to participate in this study. There is no treatment associated with this study beyond the potentially beneficial effect of Kinesio Tape™.

**USE AND DISCLOSURE OF YOUR HEALTH INFORMATION:**

By signing this form, you are authorizing the use and disclosure of individually identifiable information. Your information will only be used/disclosed as described in this consent form and as permitted by state and federal laws. If you refuse to give permission, you will not be able to be in this research.

This consent covers all information about you that is used or collected for this study. It includes

- Research records
- Records about your study visit
- Self-reported medical questionnaire documentation

Your authorization to use your identifiable health information will not expire even if you terminate your participation in this study or you are removed from this study by the study staff. However, you may revoke your authorization to use your identifiable information at any time by submitting a written notification to the principal investigator, Dr. Kaori Tamura, University

of Hawaii at Manoa, Honolulu, HI 96822. If you decide to revoke (withdraw or "take back") your authorization, your identifiable health information collected or created for this study shall not be used or disclosed by the study staff after the date of receipt of the written revocation except to the extent that the law allows us to continue using your information. The investigators in this study are not required to destroy or retrieve any of your health information that was created, used or disclosed for this study prior to receiving your written revocation.

By signing this consent form you authorize the following parties to use and or disclose your identifiable health information collected or created for this study:

- Kaori Tamura and her research staff for the purposes of conducting this research study.
- University of Hawaii at Manoa.

The individuals named above may disclose this consent form and the information about you created by this study to:

- The sponsor of this study and their designees (if applicable)
- Federal, state and local agencies having oversight over this research, such as the Office for Human Research Protections in the U.S. Department of Health and Human Services, Food and Drug Administration, the National Institutes of Health, etc.
- The University of Hawai'i for purposes of overseeing the research study and making sure that your ethical rights are being protected.

Some of the persons or groups that receive your study information may not be required to comply with federal privacy regulations, and your information may lose its federal privacy protection and your information may be disclosed without your permission

**COMPENSATION FOR INJURY**

In the event of any physical injury from the research, only immediate and essential medical treatment is available. First Aid/CPR and a referral to a medical emergency room will be provided. In the event of any emergency incidence outside the lab as a result of this research, contact your medical doctor and inform the study coordinator: Kaori Tamura Ph.D., ATC, at 808-956-3801. You should understand that if you are injured in the course of this research process that you or your medical insurance will be billed for the costs of treating your injuries.

**VOLUNTARY PARTICIPATION AND WITHDRAWAL**

Your participation in this study is voluntary. You may decide not to participate or you may leave the study at any time. Your decision will not result in any penalty or loss of benefits to which you are entitled.

Your participation in this study may be stopped at any time by the study doctor or the sponsor without your consent for any of the following reasons:

- it is in your best interest;
- you do not consent to continue in the study after being told of changes in the research that may affect you;
- you become pregnant;
- or for any other reason.

If you leave the study before the planned final visit, you may be asked by the study doctor to have some of the end of study procedures done.

**SOURCE OF FUNDING FOR THE STUDY**

This research study is sponsored by the University of Hawaii, Manoa.

**QUESTIONS**

Contact Kaori Tamura, Ph.D., ATC at 808-956-3801, Adriana Trost, BS, ATC at 303-457-3332, or Jingyu Hu, BS at (812)-391-0594 for any of the following reasons:

- if you have any questions about this study or your part in it
- if you feel you have had a research-related injury or
- if you have questions, concerns or complaints about the research

You may contact the UH Human Studies Program at (808) 956-5007 or uhirb@hawaii.edu. to discuss problems, concerns and questions; obtain information; or offer input with an informed individual who is unaffiliated with the specific research protocol. Please visit http://go.hawaii.edu/jRd for more information on your rights as a research participant.

The Human Studies Program will not be able to answer some study-specific questions, such as questions about appointment times. However, you may contact them if the research staff cannot be reached or if you wish to talk to someone other than the research staff.

Do not sign this consent form unless you have had a chance to ask questions and have gotten satisfactory answers.

If you agree to be in this study, you will receive a signed and dated copy of this consent form for your records.

**CONSENT**

I have read this consent form. All my questions about the study and my part in it have been answered. I freely consent to be in this research study.

I authorize the use and disclosure of my health information to the parties listed in the authorization section of this consent for the purposes described above.

By signing this consent form, I have not given up any of my legal rights.

_____

Subject Name (printed)

**CONSENT SIGNATURE:**

Signature of Subject Date

Signature of Person Conducting Informed Consent Discussion Date

## Appendix C: Screening sheet

Recruitment - Screening Participant Checklist

- ❑ Name:
- ❑ Birthday (Age):
- ❑ Phone Number:
- ❑ Email:
- ❑ Possible availability time:

You can check each of them, and answer it with YES or NO.

- ❑ Current lower limb injury
- ❑ Currently a candidate for knee replacement surgery
- ❑ Open wounds around knee or thigh area
- ❑ Require assistance during walking
- ❑ Skin sensitivity to tape
- ❑ Any neurological conditions
- ❑ Current back pain
- ❑ Rheumatoid arthritis of the lower body
- ❑ Unable to sit with feet flat on the ground
- ❑ Unable to extend knee to 180°
- ❑ Inability to follow the instruction

## Appendix D: KOOS

# KOOS KNEE SURVEY

Today's date: _____/_____/_____ Date of birth: _____/_____/_____

Name: _____

**INSTRUCTIONS:** This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

**Symptoms**
These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

| Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

| Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

S3. Does your knee catch or hang up when moving?

| Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

S4. Can you straighten your knee fully?

| Always | Often | Sometimes | Rarely | Never |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

S5. Can you bend your knee fully?

| Always | Often | Sometimes | Rarely | Never |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**Stiffness**
The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |



**Pain**
P1. How often do you experience knee pain?

| Never | Monthly | Weekly | Daily | Always |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P3. Straightening knee fully

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P4. Bending knee fully

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P5. Walking on flat surface

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P6. Going up or down stairs

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P7. At night while in bed

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P8. Sitting or lying

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

P9. Standing upright

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**Function, daily living**

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A1. Descending stairs

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A2. Ascending stairs

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |



For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A4. Standing

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A5. Bending to floor/pick up an object

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A6. Walking on flat surface

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A7. Getting in/out of car

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A8. Going shopping

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A9. Putting on socks/stockings

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A10. Rising from bed

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A11. Taking off socks/stockings

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A12. Lying in bed (turning over, maintaining knee position)

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A13. Getting in/out of bath

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A14. Sitting

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A15. Getting on/off toilet

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |



For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

A17. Light domestic duties (cooking, dusting, etc)

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**Function, sports and recreational activities**

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

SP1. Squatting

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

SP2. Running

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

SP3. Jumping

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

SP4. Twisting/pivoting on your injured knee

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

SP5. Kneeling

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

**Quality of Life**

Q1. How often are you aware of your knee problem?

| Never | Monthly | Weekly | Daily | Constantly |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Q2. Have you modified your life style to avoid potentially damaging activities to your knee?

| Not at all | Mildly | Moderately | Severely | Totally |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Q3. How much are you troubled with lack of confidence in your knee?

| Not at all | Mildly | Moderately | Severely | Extremely |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

Q4. In general, how much difficulty do you have with your knee?

| None | Mild | Moderate | Severe | Extreme |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |