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An Investigation of the Biomechanics of Kinesiology Tape

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An Investigation of the Biomechanics of Kinesiology Tape

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ABSTRACT

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Rose-Hulman Institute of Technology

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An Investigation of the Biomechanics of Kinesiology Tape

Thesis Advisor: Dr. Renee Rogge

Kinesiology tape has grown in popularity since its widespread use at the 2012 and 2016 Olympic Games. Manufacturers of these colorful tapes have advertised biomechanical benefits for athletes, including pain relief and muscle support, without much quantitative evidence to support these claims. The purpose of this research study was to evaluate the biomechanical aspects of kinesiology tape and how it affects subjects' muscle activity. This research study evaluated the muscle activity of subjects' low back before and after tape application during targeted, bodyweight exercises. Each subject's muscle activity, measured through electromyography (EMG), was normalized and assessed using nonparametric statistical techniques. In addition, the placebo effect was evaluated by incorrectly applying tape on half of the research participants. In general, findings indicate no significant changes to the muscle activity of the low back due to kinesiology tape, regardless of the method of application.

Keywords: biomedical engineering, electromyography, kinesiology tape, biomechanics

DEDICATION

It is with the warmest regard and a respectful heart that I dedicate this thesis work to my mom and dad for pushing me to "do my bestest," and to "always double check my work!" I am also humbled by every opportunity the Lord has granted me in education and research thus far.

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LIST OF ABBREVIATIONS

Ag/AgCl	Silver/Silver Chloride
BMI	Body Mass Index
CI	Confidence Interval
CITI	Collaborative Institutional Training Initiative
CLBP	Chronic Low Back Pain
CMRR	Common-Mode Rejection Ratio
EMG	Electromyography
IRB	Institutional Review Board
MVC	Maximum Voluntary Contraction
PI	Primary Investigator
RA	Research Assistant
RMS	Root Mean Square
ROM	Range of Motion
sEMG	Surface Electromyography

1. INTRODUCTION

Kinesiology tape became very popular after Olympians were seen wearing it at the 2012 and 2016 games. Athletes displayed the neon strips of tape emblazoned on their shoulders and other limbs as the world watched, curious about this new training aid. This intrigue made manufacturers realize the available market and to capitalize on that; the tape quickly became available on store shelves all around. With this increased availability, there was a tumult of available brands, sizes, materials, colors, and even patterns at varying prices.

Kinesiology tape commonly can be purchased as a strip of elastic and inelastic fibers that are woven together to allow for breathability of the material with an adhesive backing for application to the skin [1], [2]. This adhesive is in a wave-like pattern that allows for improved breathability of the material [1]. This adhesive pattern has also been suggested to have been generated in order to emulate the human fingerprint pattern, thus allowing the tape to give the impression of the caregiver providing continued treatment of the subject after they have left the office [3]. The tape, while extremely stretchy, must be resiliently elastic and relatively tear-resistant to better provide support to the user [2].

The purpose of this research was to evaluate the biomechanical benefits of kinesiology tape during bodyweight activities targeting the muscles of the low back. Many members of the general population tend to experience low back pain at some point in their lifetime [4]. Kinesiology tape has become popular in recent years as a possibility for helping with this common pain [5]. With stretch capabilities of up to 1.4 times its original length, it is intended to produce less mechanical retention and restriction to movement [6]. This traction on the skin is marketed as a means to promote an elevation of the epidermis, which may improve circulation and improve communication with mechanoreceptors that are just below the skin [2], [5], [7], [8].

This is proposed to result in reduced pressure on the mechanoreceptors to reduce nociceptive stimuli, or the feeling of pain [2], [5], [7], [8]. The manufacturer proposes the following benefits of kinesiology tape: facilitation of blood and lymphatic circulation; pain reduction; realignment of joints; improvement of fascial tissue alignment; reduction of muscle tension; sensory stimulation to improve proprioception; increased recruitment of motor units during muscle contraction; and possibly alteration of the recruitment pattern of muscle fibers [6]–[8]. The principle function of this elastic tape is to give provide force while minimally contacting the skin to normalize the motion of a specific area of the body [9]. This research was motivated by a class action lawsuit against KT Health, one of the major manufacturers of the tape, filed by an individual citing “unjust enrichment, untrue and misleading advertising” [10]. This study is a way to quantify some of the claimed benefits to provide consumers and health care practitioners with a quantitative resource for determining if this highly marketed tape is beneficial. The hypothesis is that kinesiology tape will not produce a difference in the activation of the muscles of the low back.

2. BACKGROUND and LITERATURE REVIEW

2.1 Overview

The surge in popularity of kinesiology tape causes people to generally be on one side or the other of the argument, either strongly supporting its use or strongly opposing it. Scientific investigations on the behavior of this tape may provide important evidence on the clinical applications of kinesiology tape for patients. The reasonable measurement of the effectiveness, or lack thereof, of kinesiology tape may lie in the change in response of the musculature of people before and after application of the tape during exercise. Prior to developing and conducting a research study, the investigation was completed to address claimed benefits, current research, and finally, types of kinesiology tape applications.

Kinesiology tape is thinner than normal tape, and is applied while applying tension to the tape, the muscle, or both [7]. The tape is manufactured in a continuous roll of 16 feet or in precut strips on a roll, with twenty 10 inch precut strips per roll [11]. The rolls are approximately 2 inches wide, while there are options for a wider 4 – inch piece to cover larger areas of the body [11]. There are several colors available, with KT Tape offering ten color variations in the cotton tape selection alone [11]. All of these options are available because there are several brands of the tape, seen in Figure 1 along with a portrayal of the thickness of the tape.

Figure 1: Several kinesiology tape brands with their pamphlets describing tape application [5]. Note how thin the tape is from the roll in the upper right corner, which still has the backing on it creating a thicker tape. The tape ranges in thickness from 0.0145 – 0.0220 inches with the paper backing still attached.

The taping method can be facilitation or inhibition of the muscle [12]. To facilitate movement, the tape should be stretched between 15-35% and to inhibit movement, the tape should be stretched between 15-20% and applied distal to proximal, or origin to insertion, of the muscle [3]. In this research study, the method was facilitation of the muscle, so it was stretched between 15-20% and applied starting lower and moving up the trunk toward the head. The stretch of the tape is not the only factor influencing facilitation or inhibition of the muscle, the direction which tape is applied also has an impact. To facilitate muscle activation, the tape should be applied from the muscle origin to insertion, which produces a concentric pull on the fascia [13]. To decrease muscle contraction, an eccentric pull on the underlying fascia by application from insertion to origin will produce the desired effect [13].

According to Leininger et al., to increase lymphatic fluid to encourage healing, the tape should be stretched approximately 10%, and to bring a joint back to natural location, the tape should have in the region of 25% stretch [3]. Very high tensions above these values may have the opposite effect and actually hinder muscle contraction and decrease joint mobility, possibly causing non-functional movement and inactivation of muscles [8]. No matter the percentage stretched, to ensure proper application and tape adherence over time, the patients' muscle is suggested to be in a stretched position when tape is being applied, the ends of the tape (the last 1-2 inches) should serve as an anchor with no tension, and the edges should be cut in a rounded fashion [3]. Generally, the healthcare professional decides what level of tension will be appropriate for the desired effect [7]. It is said that kinesiology tape should be applied at least 30 minutes prior to activity to ensure proper adherence to the skin and to decrease the chances of sweat causing the tape to detach prematurely [3]. There is also research which suggests that different colors within the same brand will have different effects, saying that some brands specify a certain color for a specific goal and some colors have even been reportedly linked to distinct mood changes and allergic skin reactions [12].

2.2 Prior Studies

Part of the motivation for this research was the class action lawsuit mentioned previously, which included a second amended complaint added for personal injury because the individual felt that KT Tape caused redness and irritation when placed on their skin [10]. The second amended complaint and class action lawsuit offers that there has not been scientific testing to provide evidence to back up the purported health benefits made by the marketing techniques, which portray Olympic and professional athletes wearing the tape [10]. This class action lawsuit caused a dispute concerning the scope of a general liability insurance policy issued by the Cincinnati Insurance Company to KT Health Holdings, LLC and KT Health, LLC [10]. Because these claims do not, according to the Cincinnati Insurance Company, seek damages for bodily injury, they are outside the scope of coverage for this insurance policy, and thus KT Health was expected to cover the cost of the damages from the false advertising class action lawsuit themselves [10].

While the scientific evidence may be lacking for the marketing claims, there have been several independent studies to analyze kinesiology tape's impact on the body. In a study by Kuyucu et al., the kinesiotherapy treatment was utilized in an attempt to solve the need for pain relief for adolescent athletes experiencing calcaneal apophysitis. This study found kinesiotherapy to be an effective treatment modality to reduce pain when compared to placebo; however, the pain scale utilized was a visual analog scale and a statistically significant result was not found [14]. A statistically significant result was found in the functional scoring from American Orthopedic Foot-Ankle Society (AOFAS), to say that kinesiotaping was more effective than placebo [14], but there was a visible difference in the two types of tape and it is of concern the athletes were aware of the differences and thus reacted accordingly, possibly biasing the results.

A study on knee osteoarthritis found no significant benefits for subjects in the areas of pain, swelling, muscle strength, knee function or knee-related health status [15]. This study utilized several taping techniques and measurements for assessing various possible benefits of kinesiology tape, though some of those measures included questionnaires, which lack documentary quantitative evidence [15]. In the interest of blinding the researcher, the tape was removed from subjects prior to assessment [15]. However, it is usually assumed that the benefits of kinesiology tape apply only while wearing the tape and the positive impact on the musculature immediately after. There are no additives to the tape which should prolong its benefits, such as an anti-inflammatory cream; therefore, the benefits would have likely been lost prior to this researcher examining subjects. It is unclear, however, from manufacturers as to their intent for the duration of the benefits of wearing kinesiology tape. Another study observed the benefits of kinesiology tape for patients experiencing myofascial pain syndrome and found the tape to significantly improve the pain level of subjects immediately and even one month after its use [16]. Also at one month after its use, there was an increase in trapezius muscle strength [16].

Kinesiology tape is not only utilized in large muscles, but has also been utilized in smaller, more precise muscles of the hand. One such study analyzed the impact of kinesiology tape on handgrip strength through three groups, one at 25-35% stretch of kinesiology tape, one at 0% stretch, and one group without tape to act as the control and found that a statistically significant increase was observed in the stretched tape group when compared to the control group after one and two days of wearing the tape [8]. It is somewhat unclear the different comparisons which were made here and there is the missed opportunity to collect paired data for a more robust paired *t*-test instead of a control group. The student's *t*-test will be affected by the natural differences in individuals' strength which will occur, instead of the ability of the paired t-test to compare each subject to themselves. A valuable aspect of this study is the use of a non-stretched piece of kinesiology tape to also record any changes simply due to the presence of the tape exerting minimal tension on the skin [8].

Much of the current research on kinesiology tape utilizes a patient survey in which they depict their level of satisfaction with the tape, possibly based on their quality of life, or their decrease in pain due to using it [7]. While patient input is valuable, it is known that there can be psychological influences and unknown biases to the ways in which people respond to surveys. Those surveys can be skewed by subjects having seen advertising using professional athletes and deciding that since kinesiology tape seems to work for professionals, it will also benefit them. With the availability of such tapes at all sorts of retailers, subjects may have applied kinesiology tape on their own or heard a report of what their friends and family have experienced. These possible biases would lead researchers to desire a less easily biased form of measurement. In this specific study, the use of electromyography equipment seemed the way in which muscle activity should be measured and avoid the biases of a patient survey. The choice of this equipment was due to its availability to the PI, the common use in practice, and a quantitative measurement.

A review article by Parreira et al. found that the studies analyzed showed kinesiology taping does not provide a statistical benefit to patients, and is not a valid intervention to be considered for those with musculoskeletal conditions [7]. However, most studies were underpowered, so more robust studies are needed [7]. A prospective power analysis was completed prior to data collection for this study assuming that the power would be at least the common threshold of 80%, to ensure that the current study would not be underpowered as well.

2.3 Electromyography Studies

Electromyography readings reveal the signal of active muscle fibers [9], and thus can be a form of measurement to mitigate the effects of a patient survey. A study by Huang et al. found the vertical ground reaction force and EMG activity to significantly increase after Kinesio taping, though the jump height, which would be most beneficial to athletes, was not statistically increased. This study utilized two types of tape, the elastic Kinesio tape and the inelastic Mplacebo tape, both applied to each subject for a different type of comparison [9]. Though beneficial in taping all subjects with both types of tape, the comparison of these two tapes appears inefficient; the lower elasticity of Mplacebo tape would tend to restrict the motion of the joint in order to fulfill its purpose of joint support and stabilization [9]. Furthermore, the Kinesio tape was applied immediately following the control jumping and the follow-up was performed 30 minutes after that, which may not have been enough time to produce greater muscle strength [9]. It also brings up the question of the adherence of the tape to the skin, which needs to be clean and sweat free upon application.

Another study was conducted using sEMG (surface electromyography) to determine if kinesiology tape had an effect on neuromuscular activity of the peroneus longus muscle of the lower leg and found that it did not [17]. The researcher utilized single-use electrodes and placed them in accordance with known standards; however, the short-time application and cutting of the tape could be the cause of the lack of statistically significant results [17]. The article does not specify the length of time the kinesiology tape was on subjects, so it may not have been long enough to allow the tape to adhere to the skin properly. With the tape being cut and thus covering a smaller surface area, it may not have been as capable of producing an effect on the surrounding tissue. An additional study controlled for muscle action speed during a barbell squat exercise did not find statistically significant results either [13]. The results suggested that kinesiology tape has such a localized effect that it cannot change the magnitude of the EMG activity, and the effects are too simple in relation to the complexity of the neuromuscular system [13].

A study by Paoloni et al. found that kinesiology tape reduced abnormal paraspinal muscle activity measured through sEMG in patients with chronic low back pain (CLBP). This study analyzed both immediate and short term effects of kinesiology tape [18]. However, some of the results were minimally clinically relevant, and the kinesiology tape was not stretched upon application other than the slight bend in the patient's back providing a small amount of stretch when they returned to an upright position [18]. There were three pieces of tape utilized and those may have generated increased involvement of cutaneous receptors due to the afferent stimuli which the kinesiology tape provided [18]. Another study analyzing the immediate effects of kinesiology tape on maximal power and muscle activity of erector spinae muscles in normal subjects found no statistical significance [19].

2.4 Electromyography Recording

As the body prepares a muscle for contraction, the muscle fibers generate an action potential, which is an electrical signal. This electrical signal, called the electromyogram, can be quantified through the connection of an electrode to the skin [20]. The electrode has a metal component (Ag/AgCl) with a surrounding gel to increase conductivity [20], [21]. The foam component adheres to the skin and the snap connector on the back connects to a wire to send the electrical signal from the electrode to the connection box [20]. All of these components are outlined in Figure 2.

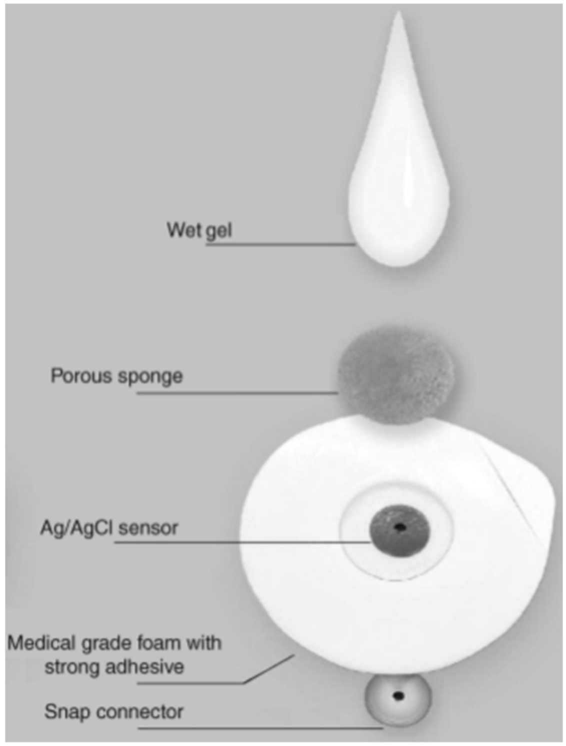

Figure 2: Components of a single-use electrode, from source [22]. The gel is to increase conductivity, while the sponge is simply a vessel to hold the gel. The Ag/AgCl sensor is the metal component for reading the signal. The foam has adhesive to attach to the skin. Finally, the snap connector attaches a wire to the connection box.

Due to the voltage potential measured by the electrodes differing in individuals, it is important for normalization and post-processing of data to analyze groups of people [20]. Therefore, the sEMG signal must be converted to a common scale for all subjects and measurement occasions; as such, the maximum voluntary contraction (MVC) is commonly used to normalize each subjects' data to themselves [20]. Further post-processing of the data includes the conversion from a fluctuating positive and negative signal to all positive values through the RMS value; this is discussed in more detail in Section 2.6.

2.5 Kinesiology Tape Application

The previously mentioned studies were on a wide variety of musculature, and thus kinesiology tape can be used for many areas, but the area of focus for this research was on the low back. One key application could be in supporting low back problems. There have been estimates that between 60-80% of the population will suffer from back pain at least one time during their lifespan [23]. This costly musculoskeletal disease requires a fix for patients to avoid chronic low back pain and missed work [23]. A study by Nilsen et al. found that men and women who reportedly exercised one or more hours per week had a lower risk of chronic low back and neck/shoulder pain than those who were inactive [24]. While a study by Álvarez-Álvarez et al. analyzed the muscles until they were fatigued to find that kinesiology tape improved the resistance to fatigue, the research described herein did not want patients to feel fatigue, but instead analyzed the muscle activity during normal exercises. The avoidance of fatigue can be a balancing act of muscle fiber recruitment; smaller motor units, or portions of the muscle, are recruited first, then larger motor units are recruited as the muscular action and force requirements increase. Larger force requirements indicate fatigue is more likely to happen, but also that the signal can be more easily detected.

More than 80% of those patients with back pain have limited range of motion (ROM), lumbar flexion, flexor muscle weakening, and muscle strength imbalance possibly due to lumbar muscular atrophy [25]. It has been found that lumbar stabilization exercises can provide adjustment of vertebral segments and an increase in dynamic stability and lumbar muscle strength [25]. Those exercises, such as a hip bridge, plank and Superman, were found to reduce pain scores while significantly increasing lumbar muscle strength and flexibility [25]. Therefore, since the exercises utilized in this study can aid in strengthening low back muscles, it would indicate they are appropriately activating those muscles for investigation of their activity. In patients experiencing low back pain, there is excessive activation of musculature in response to pain [4], and this activation may be the body's attempt to stabilize abnormal spinal structures [18]. The constant shear force on the skin from kinesiology tape could interfere with this muscle function [18], thus suggesting that the excessive activation would be inhibited and increase the ROM of the patients.

This information led to the targeting of particular muscles of the low back. The latissimus dorsi and paraspinal (erector spinae) muscles, shown in Figure 3, were of interest for this study. These muscle bodies were found by palpation, on both sides of the spine.

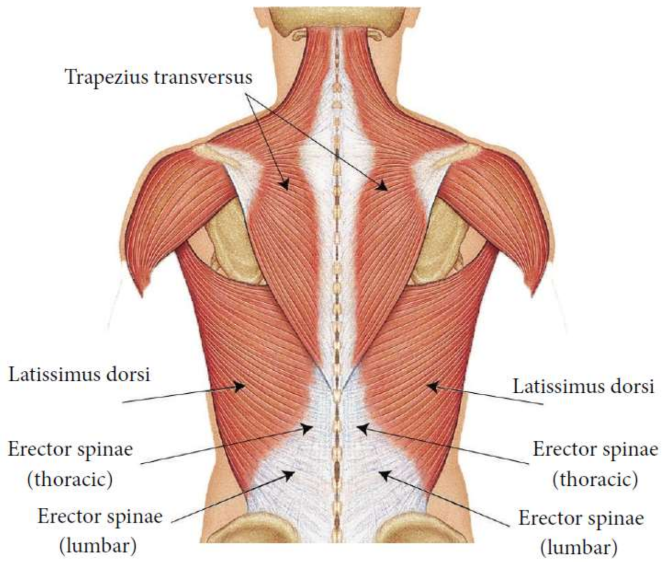

Figure 3: Pointing out the muscle location for electrode placement on the low back, from source [26]

The latissimus dorsi is the most superficial muscle [27], and thus the main target for the surface electrodes. Another superficial muscle, though deeper than the latissimus dorsi, are the erector spinae, considered intermediate in depth [27]. These more superficial muscles are longer and thus receive more overlapping nerve supply, and even with needle electrodes, the insertion is difficult and the examiner may not reach the intended muscles [27].

2.6 Evaluating Muscle Activity via sEMG

While needle electrodes are used to verify muscle activity, a more easily accessible route is through the use of surface EMG (sEMG), especially for those muscles which are more superficial anyway. Due to the nature of the muscle action potential, which is firing and the signal is continually changing, the measured EMG signal fluctuates between positive and negative values [28]. These fluctuations in the signal are exhibited in Figure 4.

Figure 4: EMG data fluctuation between positive and negative values

This fluctuation indicates the need for a method of analyzing the average amplitude over a period while not allowing it to be zero, as it has equal likelihoods of being positive or negative [28]. Therefore, the root mean square value (RMS) is an amplitude feature which can be used because the signal is altered to generate a more appropriate form for analysis [28]. RMS values are calculated by squaring the raw data, then taking the average, or mean, and finally the square root [28]. The downfall of the RMS value is that it is strongly affected by the placement of the surface electrodes with respect to the muscle's innervation zone or the muscle fiber location [28]. And this placement may be further corroborated by the issue of the signal being affected by action potentials of differing directions in fusiform muscles, such as the erector spinae, causing the signal to be exceptionally small and noisy [28]. In an effort to reduce these effects, the placement of the electrodes must be the same before and after treatment; in this research that was done by using transparencies to trace each subject's back as soon as tape was applied and before removing electrodes during their first visit. This same transparency was then utilized upon the return visit with the tape locations as a frame of reference for the electrode placement, to avoid moving the electrodes to a location which may have caused the signal to change dramatically, even if the electrodes were moved minimally.

The electrode placement is also important in noise reduction, as there are two types of noise which concern researchers using EMG recordings, ambient and transducer. The ambient noise can be removed through a notch filter, which removes noise at 60 Hz, to eliminate any interference from electromagnetic devices in the area, such as computers or power lines [20]. The transducer noise is at the interface of the skin with the electrodes where the muscle activity is converted to an electronic current of either direct or alternating current (D/C or A/C) [20]. The two straightforward ways in which the effect of this noise can be reduced are through the use of Ag/AgCl electrodes, and utilizing a bipolar electrode configuration [20]. Due to the varying nature of the EMG signal, the amplitude alone is disadvantageous for comparisons throughout a group or across various measurements and thus some type of normalization is needed; the usual form of this normalization is through the maximum voluntary contraction (MVC) readings taken of each individual [20].

Further, the muscles of the low back were targeted, not only in the interest of determining if kinesiology tape could combat the common injuries, but also due to the general lack of specific training of those muscles, the out of sight nature of the tape placement, and the general inability of people to flex those muscles more on command. These factors were considered to minimize the psychological effects of kinesiology tape. However, these factors could be considered problematic when judging the fatigue level of subjects, but the choice to include only short durations of the exercises helped to lower the impact of fatigue on the muscle activity.

2.7 Summary

Therefore, this research was motivated by the apparent lack of sufficient, quantitative data on the effectiveness of kinesiology tape. EMG measurement takes the small voltages generated by muscle action potentials and converts them to a digital form for analysis through software. This measurement can be used for large, superficial muscles, such as the muscles of the low back. As back pain is common in the general population, an easy solution for healing, such as the application of kinesiology tape, could greatly impact individuals and businesses. As such, the current study investigated kinesiology tape as a possible solution to this back pain by using EMG to quantify muscle activity and the tape's effect on it.

3. METHODS

3.1 Overview

A total of 50 voluntary subjects (21 females/29 males, mean age 29, age range 18-65 years) were recruited using fliers posted on Rose-Hulman Institute of Technology's campus; this subject recruitment flier can be viewed in Appendix A. When subjects were scheduled for testing and had a full understanding of the research and signed the Informed Consent document, which can be reviewed in Appendix B, they underwent an allergy test. After the allergy test, they performed a warm-up and their MVC was measured. Subsequently, they completed the three exercises (Superman, Bridge and Plank) in random order. Finally, the PI placed kinesiology tape on their back before they left. They were scheduled to return at minimum one hour and at maximum 30 hours after tape application. Upon their return, they completed the three exercises again with the kinesiology tape on. All subjects were randomly assigned by Minitab software to either the correct or incorrect taping conformation group. In Table 1, there are the mean and standard deviation values for demographic characteristics and in Figure 5 is a dot plot of the ages of subjects for the two taping conformation groups. A full table of the individual values of demographic data can be found in Appendix C.

Table 1: Demographic Characteristics of Subjects for Group Comparisons

Tape Conformation	Number of Subjects	Height inches (Mean ± Standard Deviation)	Weight pounds (Mean ± Standard Deviation)	Sex (Males/Females)	Handedness (Left/Right)
Correct	23	67.58 ± 4.47	163.87 ± 33.38	14/9	0/23
Incorrect	27	68.19 ± 4.07	163.13 ± 28.28	15/12	4/23

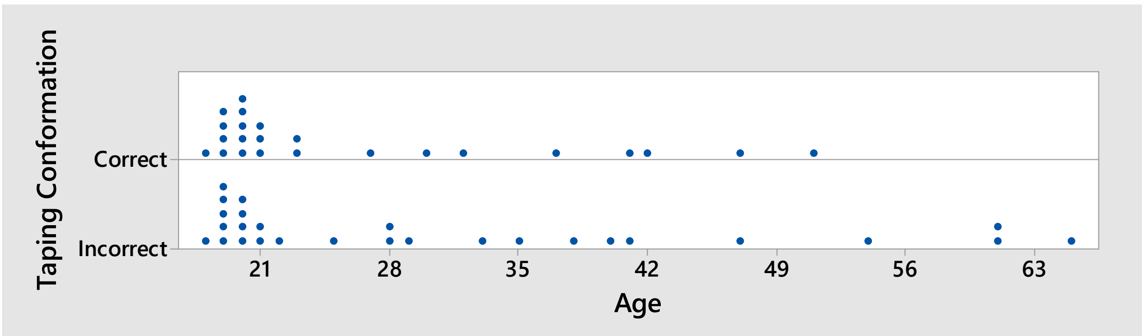

Figure 5: Dot plot of age for two taping conformation groups

This choice of two taping conformations was to aid in minimizing the possibility of subjects increasing their muscle activity, either consciously or unconsciously, simply because they were wearing the tape through an unconscious bias. Though other precautions were in place to prevent the conscious increase in muscle activity, this was an added method to minimize subject bias. Subjects were not informed of this after they were subjects, to prevent them from informing other possible subjects.

The correct taping conformation included 23 subjects and the tape was stretched between 15 and 20% of its original length for muscle facilitation, as calculated using Equation 1.

Equation 1: Percent Stretch Calculation

$$Percent\ Stretch = \frac{Post\ Stretch\ Length - Initial\ Length}{Initial\ Length} * 100$$

This measurement was determined through the RAs' marking on the tape of the portion to be stretched. Only the middle portion of the tape was to be stretched with the last inch on either end being used to anchor the tape in place and thus not being stretched as it was applied. These black markings on the nude tape were made on a flat table with a steel ruler, an example can be seen in Figure 6.

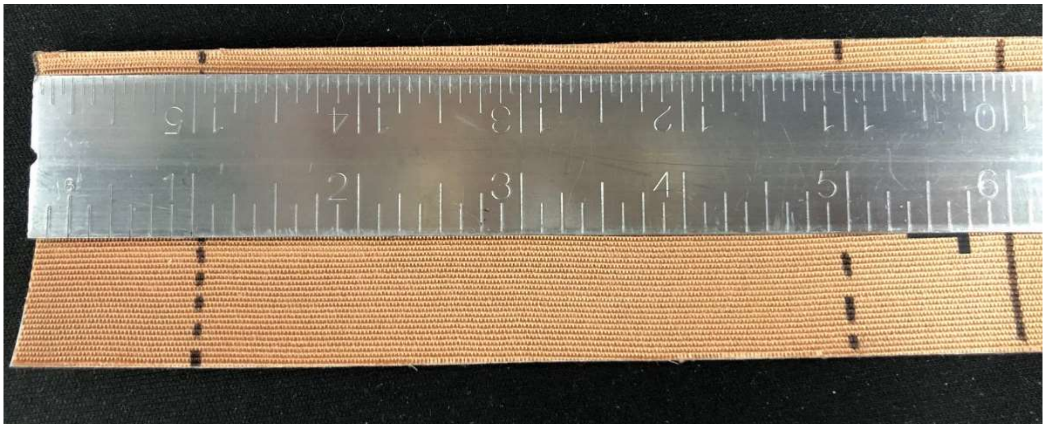

Figure 6: Kinesiology tape markings for measurement. A one-inch section on each end of the tape was used as an anchor portion, regardless of the length of tape used. The dotted lines indicate the anchor portions and the solid line would be where the tape is to be cut for that subject. The RAs would record the distance between the two dotted lines prior to giving the tape to the PI for application.

One inch was always used as the anchor at the end, no matter the requested length of tape. The incorrect taping conformation included 27 subjects and the tape was attempted to be minimally stretched. Actual stretch values occurred between 0 and 9% stretch, though 0% was the amount stretched for approximately 50% of the incorrect taping conformation subjects.

Another of the precautions to prevent the conscious increase in muscle activity included the placement of the tape and electrodes on the muscles of the low back. The low back is an area most people do not regularly, consciously train and have a difficult time deliberately contracting as compared to other muscles of the body, such as the ease with which the biceps brachii can be flexed. Further, they cannot see the tape on their back, so it is less likely to be remembered as they perform the exercises and provide the psychological effects to encourage greater muscle activity.

Further assumptions and precautions will come to light in the more in-depth methods to follow. The methods have been split into sections to provide breaks and topical changes for increased readability and for understanding the full scope of the research which was conducted. Section 3.2 provides information relating to the approval for human subject testing. Section 3.3 outlines which materials were used in this research, and justification for their selection. In Section 3.4 is an outline of the process of how each subject was prepared for data collection. This was done through the placement of electrodes and kinesiology tape, and the exercises they performed. Section 3.5 describes the data collection and analysis, how the data was maintained and the software which was used. Section 3.6 explains which exclusion criteria was used for the data. Section 3.7 outlines the relevant information for understanding how the data was processed once it was exported from the initial software's recordings. Finally, Section 3.8 describes the statistical analyses performed for this research.

3.2 Testing Approval

This human subject research received IRB approval from the Indiana State University Institutional Review Board (IRB) under the IRBNet #: 1234746-3 in July 2018. All required forms were submitted for board approval, including the Informed Consent form. All research assistants completed the basic CITI Biomedical training for biomedical research investigators and key personnel. The primary investigator (PI) also completed conflict of interest and responsible conduct of research training from CITI. Before beginning any testing, the PI for the research explained to the subject the Informed Consent form and then after the required signatures were gained, explained the Informational Document, which included the specific details of the exercises that they would be completing. The blank copies of these can be found in Appendix B. Generally, the Informed Consent document contains all of the information included in the Informational Document as well. However, in order to decrease the size of the Informed

Consent form and hopefully prevent overwhelming subjects with the large amount of information, the IRB recommended the separation of the two files.

3.3 Materials

The KT Tape® PRO brand was selected due to the availability and popularity of the brand. However, further research was conducted to compare brands of tape. This research showed that the selected KT Tape® PRO requires lower force to achieve stretch percentages between 0 and 50% than the eight other brands tested, as it was found to be statistically significantly lower than Kinesio® Tex Classic cotton/black, MyTape™ cotton/black, and RockTape® cotton/black brand. This lower load indicates the tape is not providing excessive force on the skin of subjects. The choice of the synthetic tape, KT Tape® PRO, was due to the need for tape that would remain adhered to the skin. The advertisements for KT Tape® PRO indicated it was for longer use than the KT Tape® Original. Nude tape was chosen simply to help subjects maintain a level of discreetness as they wore the tape before their second data collection. Further, the findings of the study discussed above were that the color had no effect on the behavior of the tape in tensile loading conditions for all percentages of stretch ($p > 0.1947$, $n = 22$).

Muscle activity of the latissimus dorsi and paraspinal muscles was measured using electromyography techniques, which have been shown to detect acute effects on muscles objectively [16]. These EMG readings were collected using single-use, surface electrodes in a bipolar configuration with an IX-TA-220 iWorx data recorder (iWorx Systems, Inc. Dover, New Hampshire). The surface electrodes were produced by Bio Protech Inc. and the teardrop shape allowed the size to be 43 x 45 mm with the central Ag/AgCl sensing element and Hydro-gel for adhesion [21]. The common-mode rejection ratio (CMMR) of the IX-TA-220 iWorx system is assumed to be greater than 80 dB [29]. The recording module allows recordings of up to three channels of EMG data, though only two channels were recorded in this study, left and right muscle activity. The recorder includes iWorx LabScribe v3 (version 3) Recording and Analysis Software and connects directly to a USB port on a Windows computer. The module connects to the subject by snap-leads to pre-gelled AG/AgCl electrodes for recording biopotentials, or muscle activity, at a sampling rate of 1000 samples/second and is displayed in Figure 7 and Figure 8. Also in Figure 7, the red wire in the lower left-hand side was connected to a wall outlet for grounding of the system.

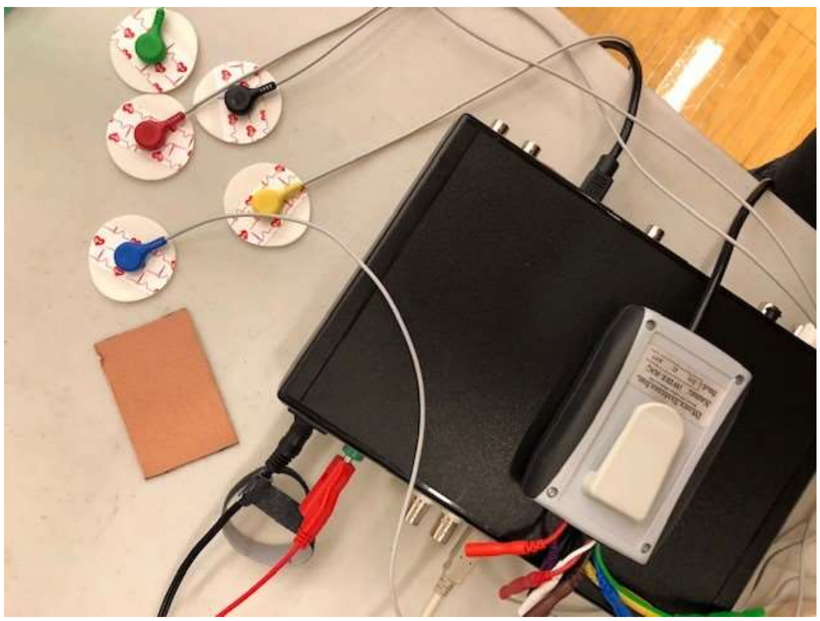

Figure 7: Top view of data collection unit with recording module placed on top. The same data collection unit and recording module were used for all subjects.

Figure 8: Front of iWorx recording module where channel connections occur, along with the port for USB connection to a computer

Other resources utilized included: masking tape for subjects to tape the excessively long wires to the recording module so they were not in the way; transparencies for tracing the approximate location of electrodes with respect to tape for electrode placement at the follow up appointment; alcohol wipes to clean the location sites of electrode and tape placement; and a flexible tape measure used to determine the length of tape required, as well as the length stretched of these resources are shown in Figure 9. Other necessary equipment that is not pictured included scissors, writing utensils, and a flat ruler for measuring the tape off of the roll.

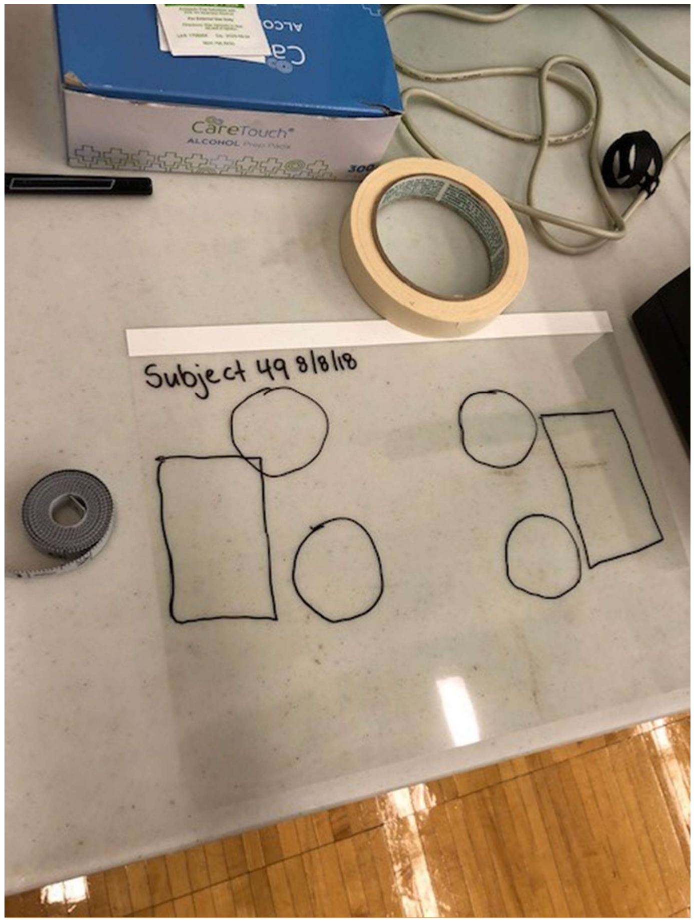

Figure 9: Subject transparency, alcohol wipes, measuring tape, and masking tape

3.4 Data Collection

Test preparation began after Informed Consent was given and a full review of the Informational Document was presented to the subject. Firstly, subjects were asked to self-report their age, height, weight, sex, and handedness. Secondly, the researcher needed to verify that the subject was not allergic to the kinesiology tape by placing a small piece of it, approximately a one-inch square, onto the subject's forearm. That piece of tape was left on the subject for fifteen minutes to confirm there were no signs of itching, redness, or irritation; no subjects showed signs of an allergic reaction during this test. During the allergy test, in the interest of being respectful of the subject's time, the subject was asked to perform a short warm-up, which included walking at a self-selected pace for two laps around an indoor track and returning for stretches led by the

PI. These stretches were selected for their ability to provide increased ROM and flexibility for the muscles of the low back [30]–[33]. The stretches included: reaching for their toes for approximately ten seconds, bringing one knee to the chest to hold with the arms while standing for approximately ten seconds (only one subject did not feel confident in their balance and thus completed this stretch while lying down), the Cat-Cow yoga pose for twenty repetitions, and finally, the Cobra yoga pose was held for approximately fifteen seconds. The final portion of the warm-up was to have subjects practice proper form of the exercises with the PI to ensure data collection went smoothly as they became more comfortable performing and holding the exercise positions.

Following the warm-up and allergy test, the PI placed the electrodes onto the muscles of the low back. In preparation for the placement of the surface EMG electrodes for recording muscle activity, the PI wiped the application location on the subject’s low back with an alcohol wipe. The PI then palpated the muscles of the low back to find the bodies of the latissimus dorsi and paraspinal (erector spinae) muscles, as seen in Figure 10. Two electrodes were placed on those muscle bodies, on both sides of the spine, for a total of four electrodes on each subject’s back.

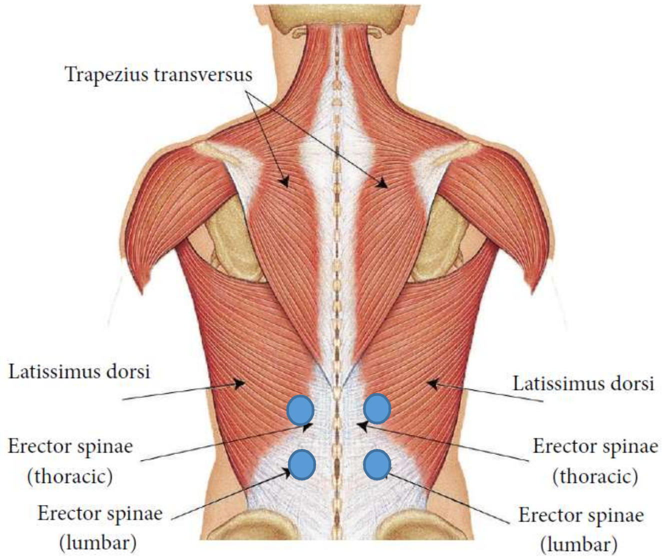

Figure 10: Muscle location for electrode placement, from source [26] with general electrode placement with blue circles.

A fifth electrode was placed on the subject's hip, at the top of the anterior superior iliac spine, or hip bone, also found by palpation, to act as a ground for the system. The connection box for the electrodes was placed by the subject onto their waistband in such a way that was comfortable and would not impact their ability to perform the exercises. The general electrode placement was shown in Figure 10, and then electrode placement with the tape applied is shown in Figure 14. While the subject was holding their shirt up in this fashion, the PI took a measurement for the desired length of kinesiology tape based on the length of the back available while maintaining a level of discreetness. The subject was then seated in a stable chair with their feet flat on the floor in front of them. They were asked to flex their low back muscles as hard as they could three times, each time over a fifteen second period in order to record the maximum voluntary contraction (MVC). These MVC recordings allowed the data to be normalized in the Data Processing stage and served as a check that the EMG signals were being measured.

Data collection took approximately ten minutes. The subject performed three exercises intended to target the muscles of the low back; these exercises are for core stabilization to promote a strong, healthy back [34]. The three exercises were completed in a random order for each subject. The length of time for each exercise was determined from a physical therapist's recommendation of holding a plank for 30 seconds, the bridge was kept the same, and the superman exercise was shortened due to higher difficulty sustaining the exercise position over time [34]. The plank, held for thirty seconds, was performed by the subject starting lying on their stomach with their legs fully extended. The subject would then place either their hands or elbows directly under their shoulders and lift up into the static, plank position, as displayed in Figure 11.

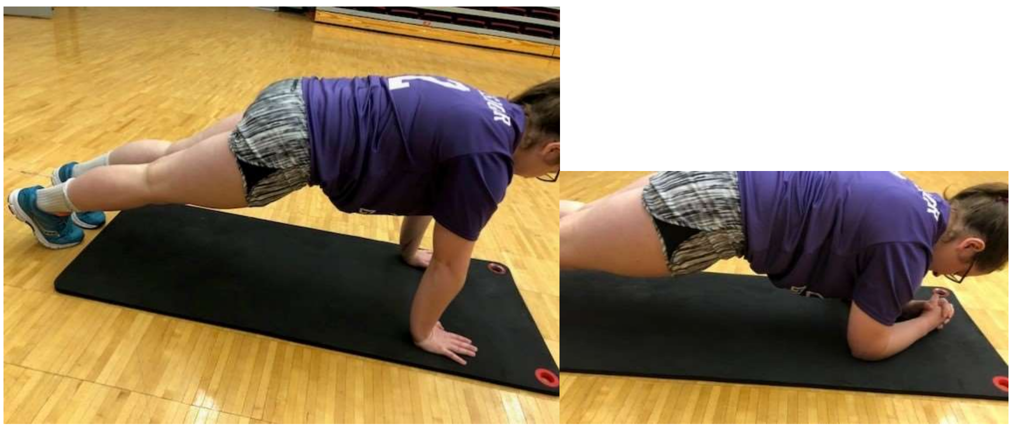

Figure 11: Plank exercise form, hands flat on the floor (left) and elbows on the floor (right). Subjects were allowed to choose whichever form felt most comfortable for them.

It was decided to allow subjects the choice of forearms or hands on the ground in order to include more possible subjects, as people prefer different forms of the plank. The PI did not feel there would be a concerning difference between the muscle activity for these exercises so long as the subject performed the exercise in the same manner upon their return for analysis with tape; the method of statistical analysis does not compare subjects to one another, only each subject to themselves. The bridge exercise was also held for thirty seconds, in which the subject started by lying on their back with their legs bent at the knee and feet flat on the floor, they then raised their hips to be in a straight line with their shoulders while keeping the head and shoulders on the floor, as in Figure 12.

Figure 12: Bridge exercise proper form

The final exercise was the Superman exercise in which subjects laid on their stomach with their legs and arms fully extended into a long line. They were then asked to raise their arms and legs up, keeping them parallel to the floor and holding that pose for at least fifteen seconds, shown in Figure 13.

Figure 13: Superman exercise proper form with arms and legs extended outward.

Upon completion of the exercises, the PI applied kinesiology tape to the muscles of the low back while the subject was in a stretched position for the low back, meaning that the subject bent forward at the waist. The tape anchor, marked by the RAs, nearest the subjects' waist was applied first and the PI used their left hand to hold the anchor while gently pulling the appropriate stretch up toward the superior portion of the subject's back. And finally, the superior anchor was applied without any stretch. The backing of the tape was only removed as that portion was applied so as not to stretch during the application of other portion. The tape was rubbed to ensure proper adherence to the skin. The tape application with electrodes in place can be seen in Figure 14.

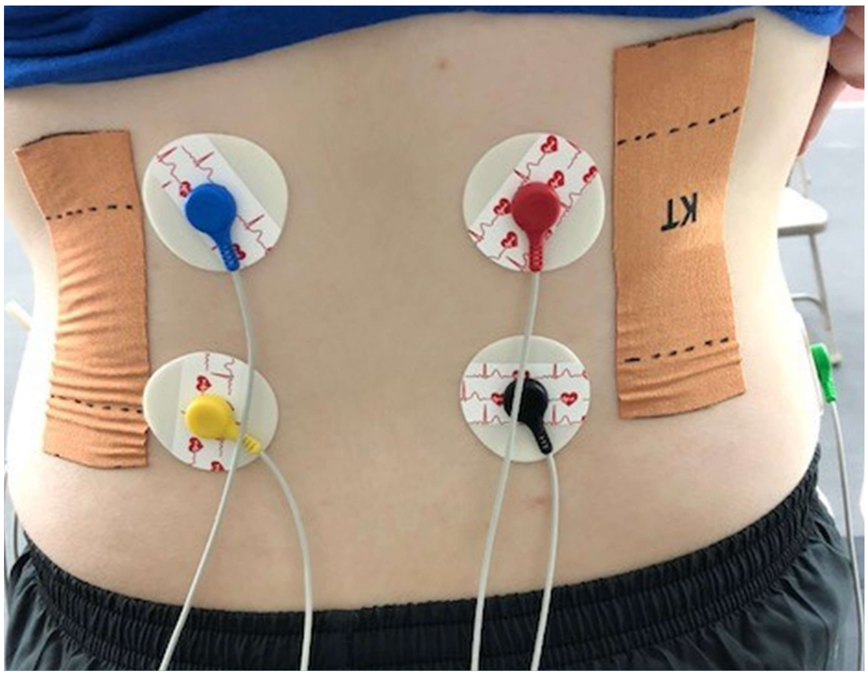

Figure 14: Electrode and tape placement on subjects' low back. Each subject used the same color coding to ensure the paired electrodes (black/red and blue/yellow) were used together on the sides of the muscle.

The PI checked the taping conformation group of the subject while the subject was completing their warm-up around the track. RAs used a color-coded Excel file to confirm the stretch percentage by recording their measurement between the anchors into the file, without reporting it to the PI. The appropriate stretch amount was confirmed by RAs when the PI reported the stretched length between the anchors, which are marked by the dashed, black lines in Figure 14. Incorrect taping was completed by placing the inferior anchor and then lying the tape on the skin attempting to prevent any stretch in the middle, and placing the superior anchor. There were not always 0% stretch values reported for the incorrect taping group because the PI may have accidentally stretched it or the forward lean of the subject may have caused slight stretch of the tape as well.

After the kinesiology tape was in place, the PI utilized a transparency to trace the approximate location of the electrodes in relation to the kinesiology tape for the same placement upon their return appointment. Subjects were scheduled for follow-up appointments within 30 hours, but at least one hour after tape application. When the subject returned, the same procedure was followed with the warm-up activities, EMG placement utilizing the previously made transparency, and exercises, except that the subject was wearing kinesiology tape for the duration of this portion of the study.

3.5 Description of the Data

Data was recorded in LabScribe v3 (version 3) software and saved under subject number, tape or no tape, and date of participation to remove personal identification. After data collection, the LabScribe file was exported to a text file which was utilized in a MATLAB R2018a program generated by the student researcher and discussed in more detail in Section 3.7, Data Processing. The validity of the data was assessed independently by the PI and two undergraduate student RAs in order to eliminate the bias of the PI desiring to keep all data for analysis. The PI and two undergraduate student RAs received individual training from the faculty advisor to visually observe the LabScribe output for discrepancies that would be indicative of some effect on the goodness of the data. Such discrepancies were flagged in a table as either a recording error, a spike in the data, data removal or interference from the subject's heart rate. A recording error may have been caused by an inadequate attachment of electrodes (possibly due to sweat or excessive hair), interference from nearby devices, power surges or any number of things to cause the recording to clearly not be normal muscle activity. Any spikes were recorded with the approximate location, or time stamp in the LabScribe file, as to when the high amplitude spike of data which was dissimilar from the surrounding data had occurred. Data removals that were recorded would simply be due to researcher error. The researcher error could be an erroneous click to stop the software, or a recognition at the time of subject testing that the data was of poor quality and was repeated, meaning that there was sufficient other data which could be analyzed and did not affect the outputs. Heart rate interference was recorded in the data table when there was a clear pattern of the heart rate shown over that exercise, which typically occurred on the right side of subjects, due to the location of the aorta running along the spine and its close proximity to those electrodes. The two undergraduate student RAs worked together, independent of the PI, to generate their own data table, which was then merged with that of the PI. Any discrepancies between the two tables were brought to the faculty advisor for a final determination of the acceptability of the data. Examples of the data output from LabScribe can be seen below in Figure 15, Figure 16, and Figure 17. Figure 15 exhibits the rapid succession of action potentials firing in a high frequency and alternating between positive and negative values. As can be seen in Figure 16, there is a large spike in the data and the frequency of the data points is not indicative of normal, or expected EMG activity; the firing of the muscles would appear to be sporadic and infrequent based on this output. Figure 17 displays the heart rate interference by the clear spikes that occur at a consistent pattern of intervals.

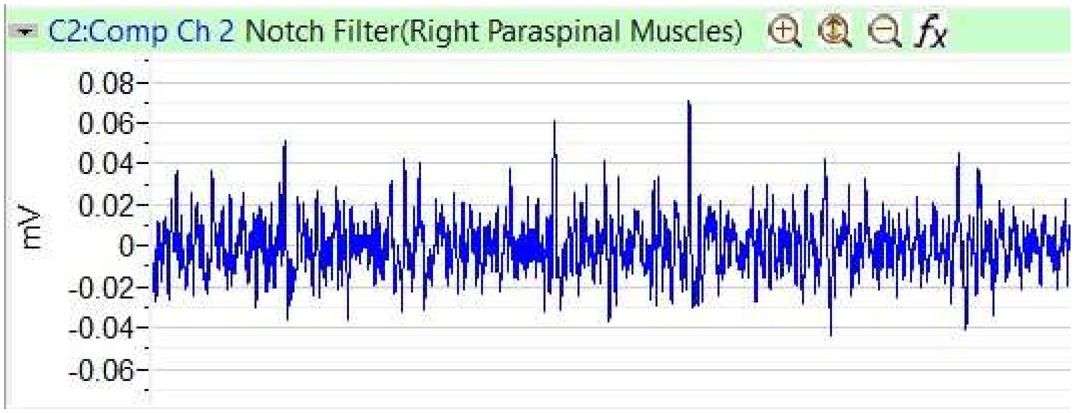

Figure 15: Example of acceptable muscle activity data from LabScribe software. Good muscle activity data shows several action potentials occurring at high frequency.

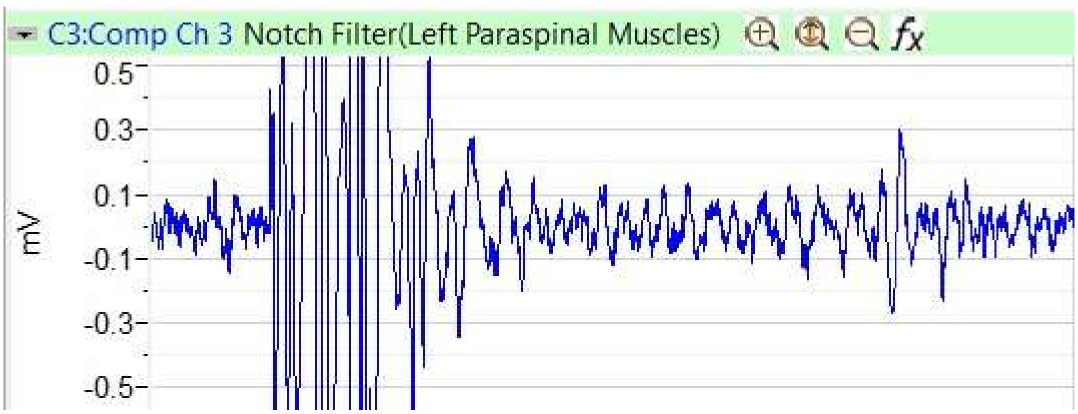

Figure 16: Example of unacceptable muscle activity data from LabScribe software. Poor data is characterized by the large spikes of data extending outside the viewing window, and the large gaps of time between the action potentials, or lower frequency of action potential firing.

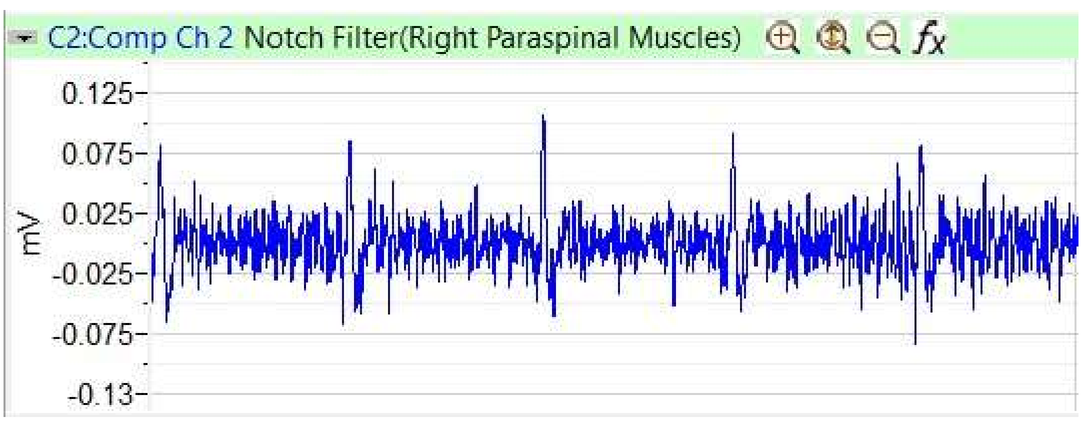

Figure 17: Data with a heart rate (HR) interference, recognized by the repeated spikes at patterned intervals. The HR interference tended to occur during the Plank exercise on the right side of the body.

3.6 Data Exclusion Criteria

Data were excluded from the processing and statistical analysis if it was an inaccurate representation of the subject's muscle activity. These inadequacies, and thus elimination of the data, could be due to the recording errors described in Section 3.5. Another reason could be that the data was too short for analysis, meaning that the ten second windows were not sufficiently long enough (i.e., not enough data to analyze). Data was also excluded if the subject did not have pre – and post – tape data for an activity. For example, the left bridge without tape data may have been usable data, but if the left bridge with tape data was found inadequate for analysis, the left bridge data for that subject would have been excluded as well.

3.7 Data Processing

Data were processed through a custom MATLAB R2018a program, after a 60 Hz notch filter had been used to remove radiofrequency noise. The program normalized the data of each subject to their personal, overall maximum voluntary contraction (MVC). The maximum muscle activity value of each of the three MVC trials was found, and then the MVC value used was the single highest value from those three trials. As is standard in EMG analysis, in order to eliminate the fluctuations between positive and negative values and smooth out fluctuations, a root mean square (RMS) calculation was performed. To do this RMS calculation, the exercise values were squared, the mean was taken, and finally the square root was taken, resulting in the appropriately transformed values for further analysis. This mean is calculated by selecting a time window over which to calculate and taking the mean of half of the points above and half of the points below. The time window for this analysis was one – second intervals, or 1000 data points. Then over that time window the points which result are representative data for taking the square root. Finally, a ten – second window of RMS data were averaged in the middle of each exercise time frame for the formal analysis in order to decrease the chance of including fatigue and remove the start and end effects. The window for the two 30 second duration exercises, Plank and Bridge, was from ten to twenty seconds. For the fifteen second Superman exercise, the analysis window was from three to twelve seconds. Further, the ten – second window is a somewhat wide range, but there is not much change from one second to the next. This results in a full picture of the exercise while eliminating excess data. It also aided in avoiding the effect of a time delay by potentially missing portions of data as the different muscle fibers fire at various rates. This method allowed for a large amount of data to be consolidated into a single, representative point for that exercise, tape configuration, and side of the body. The statistical analysis was then performed on these points.

3.8 Statistical Analysis

Prior to data collection, a power analysis was performed for a two-sided hypothesis test on the mean with 80% power, ensuring the proper number of subjects would be tested. The sample size was estimated to be 34 subjects, assuming a significance level of $\alpha = 0.05$, a standard deviation of $\sigma = 1$, and a difference of 0.5 to detect. These values were chosen based on current research in the field [35], though the actual standard deviation calculated was much lower. However, after considering the possibility of subject dropout or data recording errors, the student researcher set a goal of 50 subjects to test. Researchers compared each subjects' muscle activity when wearing the kinesiology tape to their own muscle activity when not wearing the kinesiology tape for the individual taping conformation groups. Therefore the statistical analysis for the results utilized a Wilcoxon signed rank test on the differences, which is similar to the paired t – test for nonparametric data [36]. The null hypothesis of the test assumed the median muscle activity differences to be zero. The Wilcoxon signed rank test assumptions are that the distribution of the differences are symmetrical and the data are independent. These were tested and confirmed prior to completing the statistical analysis.

The Mann-Whitney test was used to analyze the pre- and post-tape muscle activity values for all taping conformation groups together, much the same as an independent *t* – test [37]. These tests were performed to determine whether there was a difference in the median muscle activity with respect to kinesiology tape. The assumptions of the Mann-Whitney test are that the distributions have the same shape, equal variances, and the samples are independent. These were also confirmed prior to completing the statistical analysis. In order to answer secondary questions about sex differences and BMI, bootstrapping was used due to the non-normal, non-symmetric distributions of the data. The bootstrapping method constructs a 95% confidence interval (CI) based on the means. This technique samples with replacement from the difference data for a total of at least 5000 samples. From these samples, the CI was determined.

4. RESULTS

4.1 Results Overview

Results of the Matlab analysis output for the muscle activity of all three exercises, following RMS transformation and filtering, are displayed in Figure 18. In most subjects' data, the Superman exercise (yellow) generated the highest amount of muscle activity in millivolts (mV), while the Plank (orange) and Bridge (blue) exercises alternated for second and third highest muscle activity subject to subject. The Superman data was tested for 15 seconds, while the other exercises were over a 30 – second time interval.

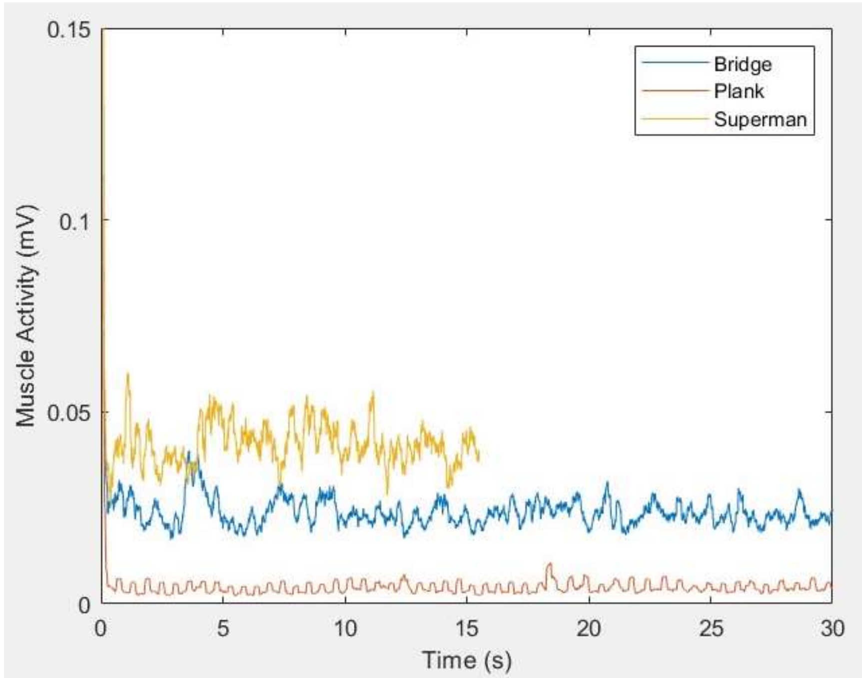

Figure 18: Matlab Graphical Output of three exercises. Superman is the highest value (yellow), then Bridge (blue) and finally the Plank (orange) had the lowest muscle activity in this particular subject. The plank data has a square shape to it due to the heart rate interference which was shown in several subjects and displayed in Figure 17.

Data from this Matlab analysis was used to generate answers to various research questions. First, the MVC was used in the Matlab analysis to normalize the data, which is further discussed in Section 4.2. In Section 4.3, the groups of taping conformation are compared to ensure similarity. Section 4.4 outlines the results of the overall research question of the tape causing a difference in sEMG measured muscle activity. Section 4.5 takes the different taping conformation groups into account and analyzes those separately. In Section 4.6, the analysis shifts to secondary questions of interest, such as if the tape impacts the two sexes differently. And Section 4.7 answers the last secondary question of interest concerning the impact of BMI on kinesiology tape's effectiveness.

4.2 MVC Results

As described, the maximum voluntary contraction (MVC) was measured for each subject through three trials. Three trials provided subjects the opportunity to acclimate to the motion and provided the highest obtainable value which subjects could contract their muscles to. Data were then normalized to the maximum value by dividing all values by the single maximum. A portion of one of the MVC recordings is in Figure 19.

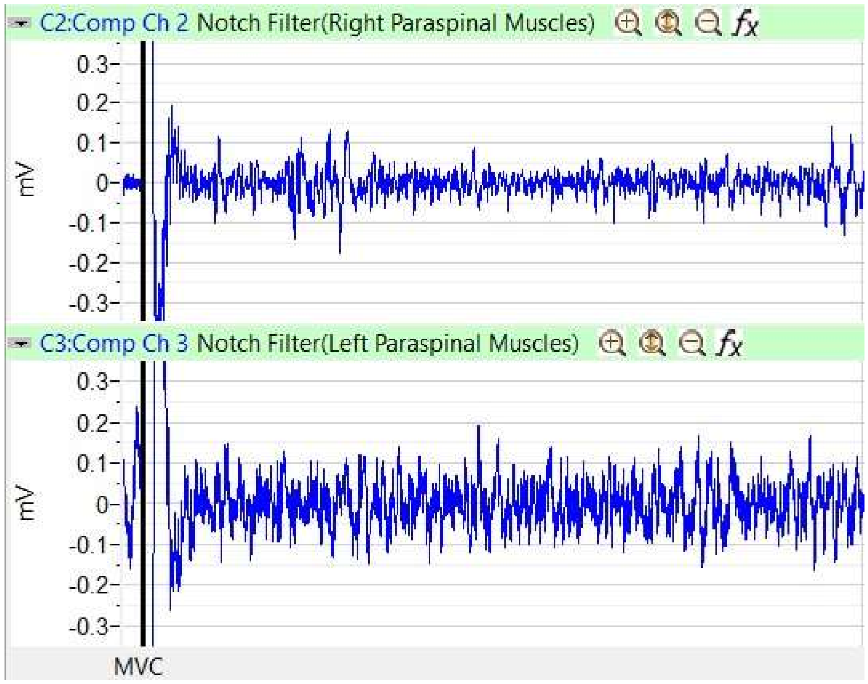

Figure 19: sEMG measurement of one MVC recording

The MVC values for the same subject are displayed in Table 2, which the Matlab program selected after the data had been exported from LabScribe software. The reported left values are much higher due to the large spikes which occurred in that specific MVC recording, and MVC1 was removed from this subject's analysis. All subjects were required to have at least two MVC values from which to find an overall maximum for analysis.

Table 2: MVC values from a random subject depicting how the MVC was calculated and used for normalizing the data.

	Right	Left
MVC 1	4.5135	43.6178
MVC 2	1.4683	12.3964
MVC 3	1.2103	11.9173
MVC Overall	4.5135	43.6178

4.3 Group Comparisons

In order to address the possible psychological effects of wearing kinesiology tape, subjects were unaware of the degree of stretch of the kinesiology tape, and thus the two groups of tape conformation were created. In order to validate that the two treatment groups, "correct" and "incorrect" taping, were similar and properly randomized, several comparisons were made of each groups' demographic characteristics, such as age, height, weight, sex, and handedness. This data was displayed in Table 1 and Figure 5 in Section 3.1.

Comparisons were completed using statistical analysis, in which only the weight for both taping conformation groups was normally distributed, and the independent t – test on the weights of the two tape conformation groups found that they were similar groups ($p = 0.934$). Age and height were found not to be normally distributed, therefore the Mann-Whitney test was used to confirm that they were also similar groups for taping conformation ($p = 0.428$ age and $p = 0.591$ height). The Mann-Whitney test was also used for sex, being a categorical variable, and found it to be similar in grouping for tape conformations as well ($p = 0.716$). These tape conformation group comparisons were completed for all fifty subjects and the demographic data for each of them prior to statistical analysis. As statistical analysis began on each of the questions of interest, subjects flowed in and out of the analysis as their data was determined usable or not for each of the individual questions. Therefore, these tape conformation group comparisons were not completed for each individual question, only for the groups in their entirety.

4.4 Primary Research Question Overall

The primary research question was tape impact on muscle forces. To evaluate this question, pre-tape and post-tape sEMG muscle activity values were compared. Mann-Whitney tests were used to compare pre-tape and post-tape sEMG values when analyzing the muscle activity of all subjects, regardless of tape conformation, or stretch percentage values. From these

Mann-Whitney tests comparing the medians, no significant differences ($p > 0.05$) were observed in the sEMG activity for subjects performing the Bridge exercise, for the left or right sides ($p = 0.837$ right, $p = 0.195$ left). During the Plank exercise, there were no significant differences for either side of the body ($p = 0.722$ right, $p = 1.000$ left). The Superman exercise yielded the same results when analyzing both tape conformation groups for left and right sides ($p = 0.776$ right, $p = 1.000$ left). This randomized study found that the presence of kinesiology tape on low back muscles of subjects did not cause a statistically significant difference in sEMG measured muscle activity.

4.5 Primary Research Question Tape Conformations

Wilcoxon tests were run on the differences in muscle activity pre-tape and post-tape when focusing on a single taping conformation, either correctly taped (15 - 20% stretched) or incorrectly taped (approximately 0% stretch). Each exercise was again assessed independently. No significant differences ($p > 0.05$) were observed in the sEMG activity for subjects performing the Bridge exercise with and without taping on the right side, regardless of the correctness of the tape application. This randomized study found that kinesiology tape, whether applied correctly or incorrectly, did not cause a statistically significant difference in muscle activity of subjects during the Bridge exercise for the right side ($p = 0.338$ correct taping, $p = 0.741$ incorrect). The results are represented graphically in Figure 20.

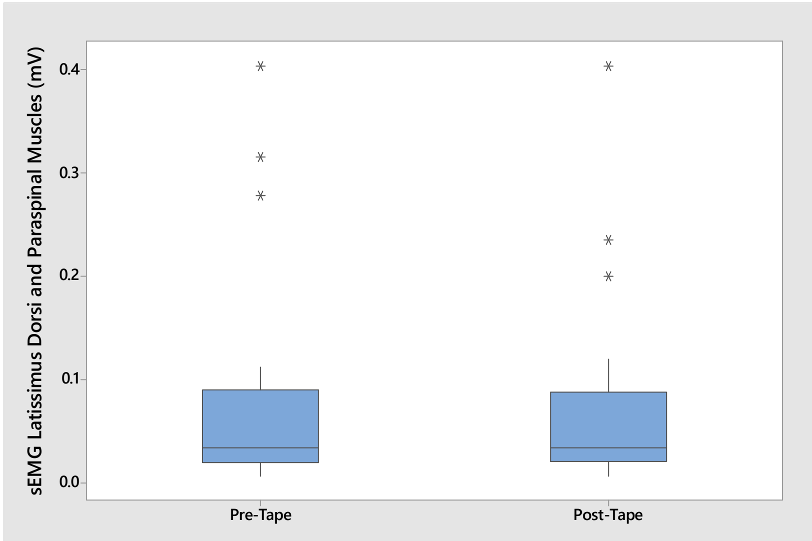

Figure 20: sEMG activity of the average Bridge muscle activity before (Pre-Tape) and after taping (Post-Tape) (for the correct taping condition, n = 23). The median is represented by the line in the middle of the boxes, and the whiskers are the lines which extend from the top and bottom of the boxes. Both the centers and the spreads of these two groups are very similar, further displaying the lack of a difference between the pre- and post-tape muscle activity.

The left side data for the Bridge exercise, while smaller in magnitude, was found to not have a statistically significant difference either; however, the correct taping conformation was very close to being statistically significant with a p – value of 0.055. The incorrect taping conformation yielded a failure to reject the null hypothesis as well, though with higher p – values ($p = 0.197$ incorrect). Failure to reject the null hypothesis means that it cannot be shown that there is a difference between the pre- and post-tape medians of sEMG muscle activity based on the evidence of this sample data.

The Plank exercise right side data exhibited the same lack of significant differences with and without taping and regardless of taping conformation ($p = 0.256$ correct, $p = 0.451$ incorrect), seen in Figure 21.

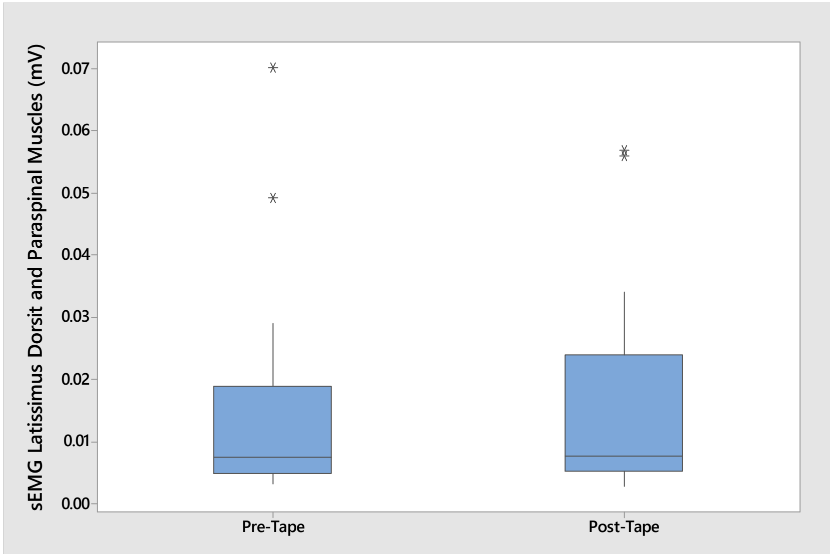

Figure 21: sEMG activity of the average Plank muscle activity right side before (Pre-Tape) and after taping (Post-Tape) (for correct taping condition, n = 22). The medians, center lines, are very close in these two graphs. While the third quartile is higher for the post-tape values, the top whisker does not stretch well above the pre-tape condition.

The p – values were all found to be high and thus the test failed to reject the null hypothesis (p = 0.141 correct, p = 0.529 incorrect), meaning the medians of the sample data cannot be said to be different, as is evidenced in the boxplot.

The Superman exercise for the right side resulted in a different finding. The correct taping conformation of subjects during this exercise did generate a statistically significant result with the Wilcoxon test (p = 0.008), and thus it can be concluded that the medians are different based on the sample data, seen graphically in Figure 22.

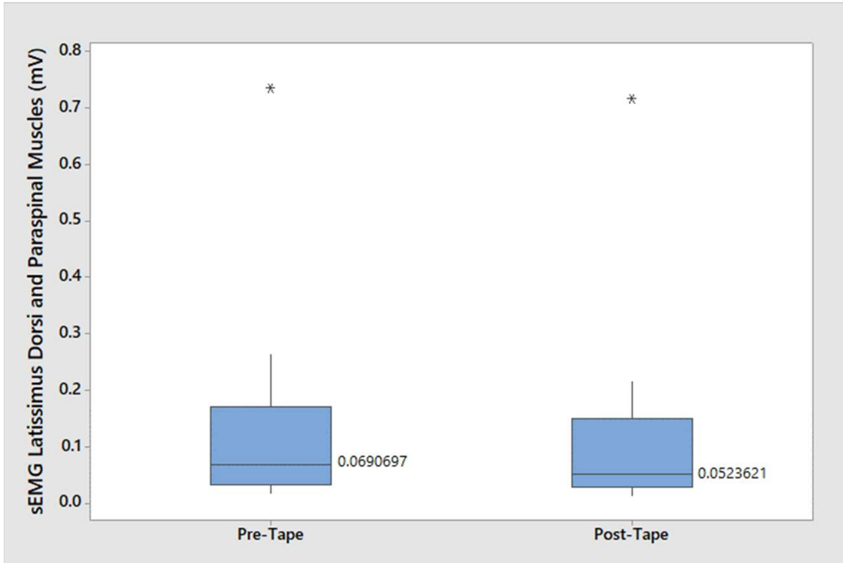

Figure 22: sEMG activity of the average Superman right side muscle activity before (Pre-Tape) and after taping (Post-Tape) (for correct taping condition, n = 22). This result was found to be statistically significant. The pre-tape median value is higher than the post-tape value, indicated by the horizontal lines through the boxes.

While this result was significant, there was no significant difference detected in the median for the Superman exercise for incorrect taping on the right side of the body (p = 0.710 incorrect).

The left side data for the Superman exercise found no statistically significant results, with all p – values greatly exceeding the alpha value of 0.05 (p = 0.724 correct, p = 0.505). All of the p – values and tests, along with the number of subjects included in each of the tests, are in Table 3, with only the right side, correct taping in the Superman exercise yielding statistically significant results.

Table 3: All p – values and tests for comparing the effectiveness of kinesiology tape in generating a difference in the muscle activity. Statistically significant results are distinguished by an asterisk (*) in the p – value column.

Exercise	Side of Body	Statistical Test	Taping Conformation	Number of subjects	*p* – value
Bridge	Right	Wilcoxon	Correct	23	0.338
	Left	Wilcoxon	Correct	12	0.055
	Right	Wilcoxon	Incorrect	26	0.741
	Left	Wilcoxon	Incorrect	11	0.197
	Right Overall	Mann - Whitney	---	49	0.837
	Left Overall	Mann - Whitney	---	23	0.195
Plank	Right	Wilcoxon	Correct	22	0.256
	Left	Wilcoxon	Correct	8	0.141
	Right	Wilcoxon	Incorrect	25	0.451
	Left	Wilcoxon	Incorrect	6	0.529
	Right Overall	Mann - Whitney	---	47	0.722
	Left Overall	Mann - Whitney	---	14	1.000
Superman	Right	Wilcoxon	Correct	22	0.008*
	Left	Wilcoxon	Correct	12	0.724
	Right	Wilcoxon	Incorrect	27	0.710
	Left	Wilcoxon	Incorrect	11	0.505
	Right Overall	Mann - Whitney	---	49	0.776
	Left Overall	Mann - Whitney	---	23	1.000

4.6 Secondary Question of Sex Differences

As a secondary question of interest, sex differences were also evaluated for the tape's effect on muscle activity. The same statistical analysis performed on the other data could not be done. This data did not meet the assumptions of normality, symmetry, and identical distributions of the data. However, the bootstrapping method allows for the bypassing of those assumptions and provides a confidence interval (CI) to answer these secondary questions. The CI calculated for the differences in sex for males and females in the Superman exercise, right side, correct taping group was [-0.018, 0.0098]. Since the CI includes zero, it can be deduced from the data that we do not have statistical evidence to suggest that the two means are not different and thus kinesiology tape did not cause a difference based on sex. The graphical output with highlighted CI is in Figure 23.

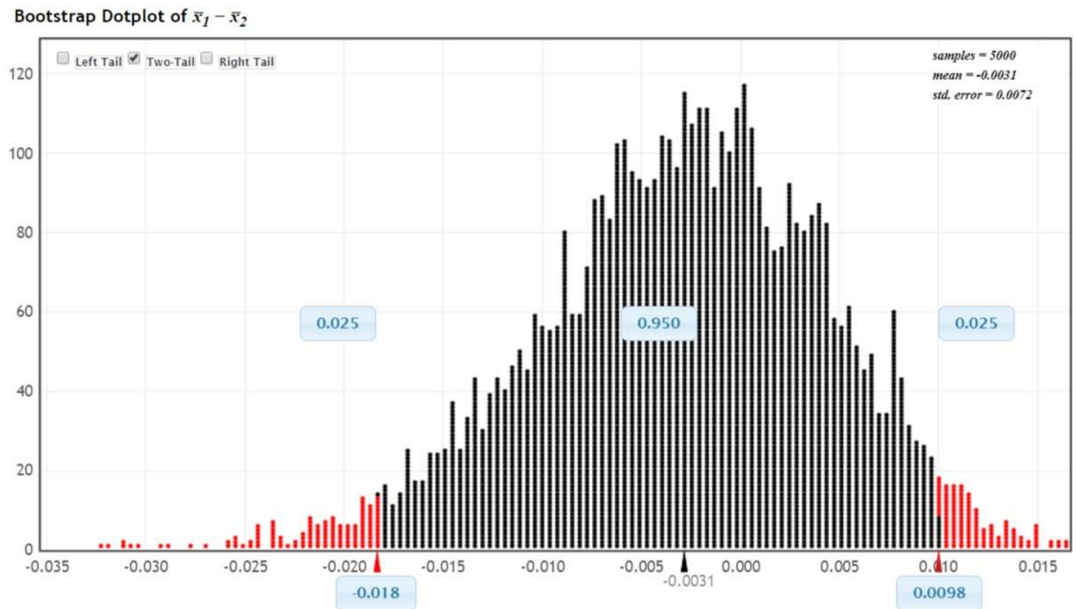

Figure 23: Bootstrapped confidence interval for the determination if sex has a statistically significant impact on muscle activity, from source [38]. The impact of kinesiology tape on males and females is not statistically different because this CI includes zero.

This bootstrapping method was utilized to determine if there were sex differences in the correct taping groups for all three exercises' right-side data. Table 4 outlines the CIs and basic information about the three groups tested using this bootstrapping method.

Table 4: Bootstrapping generated confidence intervals for the Bridge, Plank and Superman exercises, right side data with correct taping conformation to compare differences due to sex.

Exercise	Number of subjects	Number of Males	Number of Females	CI Lower Bound	CI Upper Bound
Bridge	23	14	9	0.00097	0.030
Plank	22	13	9	-0.00061	0.0054
Superman	22	13	9	-0.018	0.0098

From these CIs, the data suggests that the Plank and Superman exercises exhibited no differences due to the sex of subjects, because the CIs include zero. However, the Bridge exercise CI does not include zero. Therefore, the null hypothesis could be rejected and it can be hypothesized that there is a difference between how males and females responded to the kinesiology tape during the Bridge exercise. The range of the CI predicts the difference in means for male and female subjects' sEMG muscle activity. The difference is calculated as female minus male, so the difference in pre- and post-tape muscle activity of correctly taped females is higher than those differences for males. In other words, the post-tape activity of females is higher than their pre-tape activity, and that difference is higher than the difference exhibited by males in their pre-tape and post-tape activity.

4.7 Secondary Question of Body Mass Index

Another secondary question of interest was whether the body mass index (BMI) of subjects caused a change in the impact of kinesiology tape. The same methodology as the sex differences was used to compare different BMI values. From "The U.S. Department of Health and Human Services", their calculation and ranges for normal BMI and overweight/obese were utilized in this bootstrapping method [39]. The CIs all included zero, suggesting that there was no difference between the two BMI groupings, seen in Table 5.

Table 5: Bootstrapping generated confidence intervals for the Bridge, Plank and Superman exercises, right side data with correct taping conformation to compare differences due to BMI.

Exercise	Number of subjects	Number of Normal BMI	Number of Overweight/Obese	CI Lower Bound	CI Upper Bound
Bridge	23	10	13	-0.018	0.021
Plank	22	10	12	-0.0046	0.0027
Superman	22	9	13	-0.0053	0.025

5. DISCUSSION

At the core of this research was the question of whether or not kinesiology tape would cause a change in muscle surface electromyographic activity. Each of the three exercises were assessed independently. In most exercises, the addition of kinesiology tape did not yield statistically significant differences in the sEMG recorded activity. However, the Superman exercise, the right-side data for correctly taped subjects did yield a statistically significant result, as well as when sex was considered in the Bridge exercise. These results provide viable information because of the many controls and precautions taken. Subjects were randomly recruited from the campus community as well as randomly assigned to the tape conformation groups. Subjects were unaware of these tape conformation groups and led to believe they all received proper taping. Therefore, they should have all reacted in the same manner to the tape, possibly feeling the psychological benefit to increase performance. There was also randomization in the order of their exercises to prevent a familiarity bias. The single PI always applied the electrodes and the tape, along with utilizing a transparency for further assurance of the same placement of electrodes for both sessions. The same instrumentation for measuring EMG was used for all subjects to avoid the threat to internal validity. Statistical power was also taken into consideration. All of these precautions were taken to improve the validity of the experiment, and thus allow researchers confidence in the results.

While these precautions were taken, no experiment can be executed perfectly. Though all three exercises were body weight exercises, and acted as positive controls, the muscle activity could have varied in how much of a change was experienced since muscle recruitment differed. The results showed that the only statistically significant difference was in the correct taping conformation of the Superman exercise, in which the medians of the pre-tape and post-tape muscle activity are distinctly different. This significance could be due to the higher amplitude of muscle activity generally seen with the Superman exercise, as seen previously in Figure 18.

Due to proximity to the statistically significant threshold for two exercise groups, retrospective power calculations were completed. Those were for the Superman Right Correct and the Bridge Left Correct groups. Power calculations based on the standard deviation of the difference calculated between pre- and post-tape muscle activity are in Table 6. The standard deviations and sample sizes are shown, and the difference to detect was 0.01. This difference to detect was based on the mean of differences for the Superman exercise correct taping on the right side, as it yielded a statistically significant result. This was realized to be a more appropriate difference to detect following the analysis. The previously used 0.5 was larger than required, though that range had been successfully utilized for other studies. It is likely that the muscle activity herein is much lower than other studies, indicating the need for a lower clinically relevant difference. If the prospective power analysis had utilized the lower difference, the sample size would have increased substantially into the thousands of subjects, making the research unfeasible in the timeline allotted.

Table 6: Power calculation information and calculated power. Only two exercises are included due to either being statistically significant or very close to the 0.05 value.

Exercise	Side of Body	Statistical Test	Taping Conformation	Number of Subjects	*p* - value	Standard Deviation	Power (%)
Bridge	Left	Wilcoxon	Correct	12	0.055	0.001	100
Superman	Right	Wilcoxon	Correct	22	0.008*	0.016	77.3

From the demographic information collected, subject sex was analyzed as a possible impact on the effectiveness of the tape. The physiological differences between male and female led to the curiosity of whether those would impact muscle activity when wearing kinesiology tape. It was shown that sex did not greatly impact the muscle activity, with the only statistically significant result occurring during the Bridge exercise. And due to this CI being close to including zero, it cannot be said the two sexes greatly differ from one another.

The role of BMI and its influence on how kinesiology tape impacts muscle activity was also of interest; specifically, does a higher BMI indicate less effectiveness of the tape due to the underlying muscles being obstructed from the tape in the presence of more soft tissue? This result was deemed not statistically significant based on the CIs calculated from the bootstrapping method. Therefore, based on the data collected in this study, it cannot be said that a difference in BMI causes a difference in the impact of kinesiology tape.

It was the original intention of researchers to determine if handedness influenced the muscle activity readings which were taken, and data was collected accordingly. However, the data from the left musculature was generally of poor quality, as classified in the previous discussion. There may have been technical malfunctions with the equipment that was not noticed until after data collection. This preliminary misjudgment of the data was likely due to the assumption that most people are not left-handed, and thus their muscle activity should generally be lower on the left side. However, this was clearly not the case as left-handed subjects also experienced poor data on the left side and the muscle activity, upon further investigation, was found to be improperly recorded for those subjects as well. Therefore, this would eliminate the idea that it would simply be low activity on the left side. The recording errors could be due to the use of only a single reference electrode on the superior iliac spine of the subject on one side of the body. This side of the body was not the same on each subject, though generally it was placed on the right side. The subjects made the decision on which side of the body they would be most comfortable having the connection box of the equipment hooked to. Since most subjects were indecisive on this question, the PI placed the reference electrode on the right side, as that was generally more easily accessible with the room layout and where subjects were located. Therefore, the placement on the right side provided a better reference for the right-side data. This impeded the left side from having a proper reference electrode, causing deficient data on that side.

When using surface electrodes, instead of intramuscular electrodes, placement is key. The assumption used to be that placing electrodes over the muscle belly was the best placement because of the ease of muscle identification through palpation and the size of this area should cause it to exhibit the largest EMG signal. However, it has been found that this assumption may not be correct when analyzing fusiform muscles, or those in which the fibers run in a uniform vertical direction, parallel to the skin [28]. The resulting signal in this electrode placement may be small and noisy, due to the action potentials traveling in opposing directions [28]. This cancellation could have been the cause of the errors seen with the left side data of subjects, as the paraspinal muscles are classified as fusiform muscles, resulting in that data being removed. If this research were to be repeated, the electrodes and tape locations could be switched so that the electrodes were placed more directly over the latissimus dorsi muscle, which is a pennate muscle. The pennate muscles are not shown to have the same issue of cancellation, as their fibers are not parallel to the skin, and are instead at an angle from the spine toward the lateral aspect of the shoulder [28]. This shift of the electrode placement could be affected by the layers of subcutaneous fat and skin which may decrease the sEMG signal due to their anisotropic nature acting as a spatial filter [20], which is what led to the question of the impact of BMI on the muscle activity.

6. LIMITATIONS

Limitations of this study include the PI not being formally trained in kinesiology tape application. She did undergo training sessions from those who have been formally trained, but there was not adequate time or finances to undergo formal training herself. Further, this lack of formal training meant that muscle location was identified solely by palpation of the muscle without a measurement from a bony landmark.

A further limitation is the population from which subjects were selected, or selection bias. This population was limited to those on the campus of Rose-Hulman Institute of

Technology during the months of June through August. While randomly assigned to the correct or incorrect taping groups, the sample itself likely differed from the true United States population. Because it is a college campus, the selected subjects were younger than most, or there could have been a missing age group because the subjects tended to be students or faculty and staff at RHIT.

A study by Juchler et al chose to cut the kinesiology tape to be able to place the electrodes in the same location as the tape. This was seen as a limitation because it decreased the area of contact between the kinesiology tape and the skin. Thus, kinesiology tape in this experiment was placed next to the electrodes. However, not cutting the kinesiology tape may have created another limitation by shifting the kinesiology tape to not be directly on the muscle body. The back has a limited surface area upon which all of these items can be placed; therefore, the PI had to determine which locations to compromise. The PI chose to prioritize the placement of the electrodes onto the muscle body and place the tape secondary to that. This was due to the order of their placement, as testing was done with electrodes alone prior to tape placement, along with the desire to obtain clear muscle readings from the surface electrodes.

7. CONCLUSION

This research has shown that kinesiology tape, while a viable option for some injury treatment, does not have a direct effect on the muscle activity of subjects performing body weight activities. While these results are limited to three body weight activities, they can be indicative of other situations of muscle activity. One would assume the isometric contraction of body weight exercises with the consistent force application would predict values for concentric and eccentric contraction of those same muscles. Further, lengthening of muscles causes a decrease in conduction velocity of EMG readings, which isometric contraction helps to mitigate.

This tape may generate a placebo effect through the psychology involved in marketing, which can help some patients; however, the results of this study do not suggest it should be utilized to generate a difference in muscle activity in vast patient clientele.

8. FUTURE WORK

As stated previously, the proposed benefits of kinesiology tape include: facilitation of blood and lymphatic circulation; pain reduction; realignment of joints; improvement of fascial tissue alignment; reduction of muscle tension; sensory stimulation to improve proprioception; increased recruitment of motor units during muscle contraction; and possibly alteration of the recruitment pattern of muscle fibers [6]–[8]. This long list of benefits of kinesiology tape can propel several future studies focusing on each of those individually or in a more collective manner. This body of research analyzed the effect on muscle tension, which is a single entry in the long list of marketed benefits. The benefit of increased blood and lymphatic circulation to the area could be analyzed through ultrasound technology and was planned to be included in this study. However, this was not feasible with the available ultrasound equipment. There are also options for the assessment of joint alignment through goniometer measurement. Furthermore, an additional analysis for the Superman exercise may be beneficial with its statistical significance; adding more subjects which only perform the Superman could help to determine if the statistical significance was warranted. These reasons suggest that the field of studying kinesiology tape is open for additional investigation to determine its effectiveness.

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APPENDICES

Appendix A: Subject Recruitment Flier

Appendix B: IRB Documents

Appendix C: Subject Demographic Data

Appendix D: Raw Data for Analysis

APPENDIX A: Subject Recruitment Flier

IRBNet #: 1234746-3
Approved Date: July 2, 2018
Expiration Date: May 23, 2019
Indiana State Institutional Review Board

BIOMECHANICS OF KINESIO TAPE STUDY

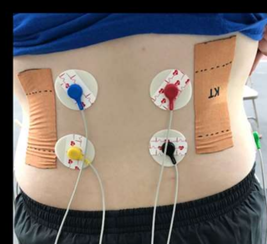
BIOMEDICAL ENGINEERING THESIS RESEARCH

Kinesio Tape has recently become very popular among the athletic community for its advertised ability to reduce pain and increase performance. Masters candidate, Jessa Ward, along with advisor, Dr. Renee Rogge, are conducting a research study to determine the effectiveness of Kinesio Tape on the muscles of the low back.

If you are between the ages of 18-65 and capable of completing three bodyweight exercises, you are invited to take part in this research study. Subjects will perform the exercises while their muscle activity is recorded.

This study will use electromyography (EMG) equipment. Research will be conducted in the Student Recreation Center on Rose-Hulman Institute of Technology's campus during the summer of 2018.

HAVE YOU EVER BEEN CURIOUS ABOUT THE COLORFUL TAPE THAT ATHLETES WEAR?



For more information, contact Jessa Ward at wardjb@rose-hulman.edu.

APPENDIX B: IRB Documents

CONSENT TO PARTICIPATE IN RESEARCH

INVESTIGATION OF THE BIOMECHANICS OF KINESIOLOGY TAPE

You are asked to participate in a research study conducted by Jessa Ward and Dr. Renee Rogge from the Department of Biology and Biomedical Engineering at Rose-Hulman Institute of Technology. This study is being conducted as a graduate thesis research project. Your participation in this study is entirely voluntary. Please read the information below and ask questions about anything you do not understand, before deciding whether or not to participate.

You have been asked to participate in this study because you are over 18 years of age and can understand and follow the written and verbal instructions and are able to safely perform activities which will engage the muscles of the low back. Approximately 50 subjects will participate in the study. You should not participate in this study if you have: been diagnosed with chronic low back pain, had an allergic reaction to kinesiology tape or electromyography pads (such as redness, itching, swelling, or rash), any open wounds, skin infections, active cancer, deep vein thrombosis, kidney disease, or congestive heart failure.

- **PURPOSE OF THE STUDY**

The purpose of this research study is to evaluate the biomechanical aspects of kinesiology tape and how it affects your muscle activity. Kinesiology tape has become very popular after many have seen Olympic athletes wearing it, and yet there is not much numerical evidence of how effective it is. Most studies have simply asked subjects to fill out a questionnaire of how they feel when using the tape. This study aims to quantify any benefits which may come from the use of kinesiology tape placed on the low back by measuring the muscle activation through the use of electromyography (EMG) equipment.

- **PROCEDURES**

If you volunteer to participate in this study, you will be asked to perform several tasks which are outlined in the attached Information Document.

- **POTENTIAL RISKS AND DISCOMFORTS**

The removal of the electrode pads may cause some short-term physical discomfort and will feel similar to the removal of a strong adhesive bandage from the low back. Electrode pad removal may result in tugging or removal of any hair in the area. To minimize your discomfort, the student researchers can either help you remove the electrode pads or you can remove them yourself. If you prefer, you can wear the electrode pads until they loosen naturally and remove them at a later time, much like an adhesive bandage.

There is a slight risk that you could have a sensitivity to the electrode pads used during the experiment which may result in a temporary rash after removal. Alcohol pads will be available for you to clean the area and remove the gel, if you desire to do so.

In the unlikely event of an injury, there are athletic trainers and sports staff immediately available in the Student Recreation Center while Emergency Services (911) responds. There is no compensation for participation in this research study. There is no compensation or treatment for injuries that may occur during the study.

- **POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY**

There are no direct benefits to participating in this study, but there are some possible general benefits to others if researchers obtain a better understanding of kinesiology tape biomechanics. Many people experience low back pain at some point in their lifetime and kinesiology tape may be an aid in minimizing that pain to help people continue exercising and performing activities of daily living. This study will quantify an aspect of kinesiology tape use - muscle activity - that is not currently available. This information will inform the biomechanics community about kinesiology tape and its possible uses.

- **CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by saving all files with a unique code that is assigned to you. Your name and identifying information will not be associated with any of the data files that are collected. The data files will be kept on the password-protected computers which are only accessible by the student researchers and the faculty sponsor. Upon the completion of the study, a back-up of the data will be kept on a secured external hard drive in the faculty sponsor's locked office at Rose-Hulman Institute of Technology and all the backed-up files will be removed from the laptop computers.

No individual's data will be released to any other party for any reason. The final results of the study will be presented in the form of tables and/or graphs and no individually identifiable information will be reported.

- **PARTICIPATION AND WITHDRAWAL**

You can choose whether or not to participate in this study. If you volunteer to be in this study, you may withdraw at any time without consequences or penalties of any kind or loss of benefits to which you are otherwise entitled. You may also refuse to answer any questions you do not wish to answer. If you wish to withdraw from the study *after* data collection, you must contact the faculty sponsor (Dr. Renee Rogge) within 48 hours after the experiment at 812-877-8505 or by e-mail at rogge@rose-hulman.edu.

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about this research, please contact

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5500 Wabash Avenue
Terre Haute, IN 47803
Cell: 812-239-1812
Email: rogge@rose-hulman.edu

- **RIGHTS OF RESEARCH SUBJECTS**

If you have any questions about your rights as a research subject, you may contact the Indiana State University Institutional Review Board (IRB) by mail at Indiana State University, Office of Sponsored Programs, Terre Haute, IN 47809, by phone at (812) 237-8217, or e-mail the IRB at irb@indstate.edu. You will be given the opportunity to discuss any questions about your rights as a research subject with a member of the IRB. The IRB is an independent committee composed of members of the University community, as well as lay members of the community not connected with ISU. The IRB has reviewed and approved this study.

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I confirm that I have not been diagnosed with chronic low back pain and I have been given a copy of this form.

____
Printed Name of Subject

____ _________________________
Signature of Subject Date

____
Printed Name of Student Researcher

____ _________________________
Signature of Student Researcher Date

Informational Document

INVESTIGATION OF THE BIOMECHANICS OF KINESIOLOGY TAPE

- **PROCEDURES**

If you volunteer to participate in this study, you will be asked to do the following things:

Prior to the experiment (15 minutes)

Note: All of the equipment described herein is available for you to inspect in the Multipurpose Room at the Student Recreation Center (your current location) at any time while you review this document.

1. The researchers will place a small piece (approximately one (1) inch square) of kinesiology tape on your forearm to insure that you are not allergic to it. We will wait at least fifteen (15) minutes to insure that there is no sign of a reaction, such as redness, itching, swelling, etc. While waiting for the completion of the allergy test, the researcher will ask if you have any questions about the exercises you will be performing.
2. While waiting for confirmation that you are not allergic to the kinesiology tape, you will be asked to perform a short warm-up by walking or running at a pace of your choosing around the indoor track of the Student Rec Center for two laps.
3. Then you will be asked to perform simple stretches to go through the range of motion as you prepare for the exercises, some stretches you may do are: toe touches, knee to chest stretch, Cat-Cow yoga pose, and Cobra stretch.
4. You will then perform a few practices of the exercises that you will be doing as a further warm-up and so that you understand the proper form.
5. You will also be asked to self-report your gender, height, weight, and handedness to one of the researchers to record it.

Experimental Preparation (15 minutes)

1. A student researcher will begin with the placement of electrodes onto the low back.
2. To help prepare your skin for placing the surface electrodes to measure electrical activity of the muscles of the low back, a researcher will use an alcohol wipe to clean the skin where the electrodes will be placed. A researcher will indicate the locations of the electrodes to you prior to this by indicating the locations in the photo below, Figure 1.

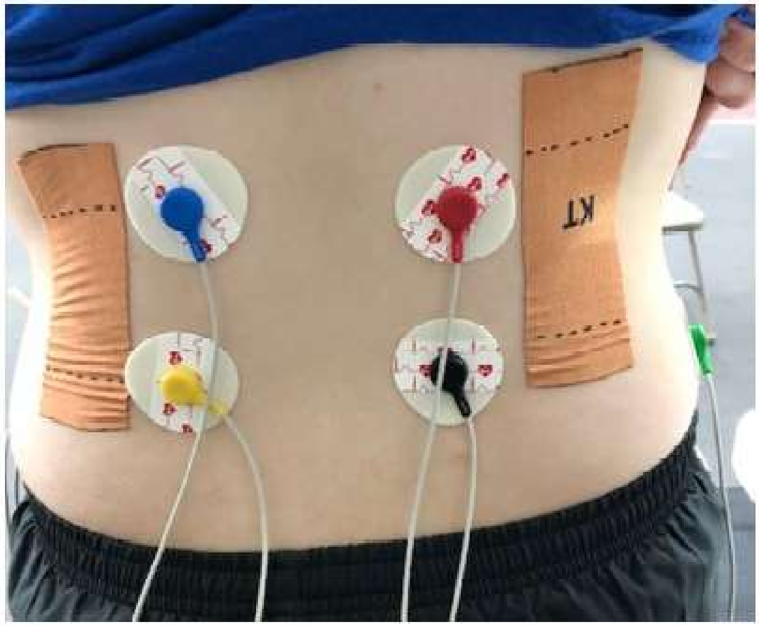

Figure 1: Electrode Placement Locations and Kinesiology Taping Conformation

3. A student researcher will place two electrodes on the latissimus dorsi and paraspinal muscles of your low back, the black and red and blue and yellow dots in the above figure. The muscle will be palpated on each individual to ensure the electrodes are placed on the body of the muscle. A student researcher will also place a single electrode on your hip at the top of the anterior superior iliac spine, seen as the green dot in the above figure, to act as a ground. While the electrodes are being placed, the researcher will take a measurement of your back, for the length of the pieces of kinesiology tape.
4. Once the electrodes are attached to your low back, you can place the connection box on your waistband.
5. You will be asked to contract the muscles of your low back as hard as you can three times as you sit on a chair, a researcher will explain a method for doing this. This will allow the researchers to verify that the electrical signals are being clearly received prior to the beginning of the experiment.

Data Collection 1 (10-15 minutes, including evaluating the quality of the data and saving the files)

1. You will perform three (3) exercises, in random order, which are intended to focus on the activation of the muscles of the low back.
2. One of those exercises will be to hold a plank for at least 30 seconds. A plank is performed by starting laying down on the stomach with the legs fully extended. By placing the hands directly under the shoulders and pushing yourself up, into a pushup position, with your body parallel to the floor, you are doing a plank. If it is more comfortable for you, you can complete the plank by placing your forearms on the ground.

3. Another exercise will be what is called a Superman exercise. This is completed by laying on the stomach with the legs and arms fully extended into a long line. You will then raise the legs and arms up, while keeping them parallel to the floor and hold for at least 15 seconds.

4. The final exercise will be what is called a bridge exercise. You will lie on your back with hands resting under the low back to cushion the electrode pads. Your legs will be bent at the knee and feet flat on the floor. You will then raises your hips to be in a straight line with your shoulders, while keeping your head and shoulders on the floor. You will hold this position for at least 15 seconds.

5. This completes the first circuit of exercises. Then, a researcher will place kinesiology tape on your lower back in the conformation shown above in Figure 1. A researcher will also mark a transparency of your back to insure that the electrodes can be placed in the same location at your return visit.

6. You will be asked to leave the tape on your low back and return within 30 hours from the application of the tape on your low back. You will not be restricted as to your daily activities, you can still bathe with the tape on, researchers simply ask that you take care when drying so as not to pull on the tape.

Data Collection 2 (10-15 minutes, including evaluating the quality of the data and saving the files)

1. Upon your return, you will be asked to perform a short warm-up by walking or running briskly around the indoor track of the Student Rec Center for two laps and performing the same stretches.

2. The electrodes will be placed in approximately the same location as previously, using the transparency which was created at your first session.

3. You will perform the same three (3) exercises in random order.

4. The researcher will then remove the electrodes and can also remove the tape for you if you wish, and your portion of the study has come to a close.

The data collected during the experiment includes muscle activity recorded from each of the three exercises. You will not be identifiable from this information since you will only appear as numerical values and a unique subject identifier.

APPENDIX C: Subject Demographic Data

Table 7: Full Table of Demographic Data for Subjects

Tape Conformation	Age	Height (inches)	Weight (lbs.)	Sex	Handedness
Incorrect	19	64	155	F	Right
Incorrect	40	64	140	F	Right
Incorrect	21	72	180	M	Right
Incorrect	19	70	175	M	Left
Incorrect	54	64	131	F	Right
Incorrect	28	64	125	F	Right
Incorrect	20	65	127	F	Right
Incorrect	19	70	180	M	Right
Incorrect	18	67	203	M	Right
Incorrect	35	68	143	F	Right
Incorrect	47	72	212	M	Right
Incorrect	65	65	130	F	Right
Incorrect	61	64	153	F	Right
Incorrect	61	70	194	M	Right
Incorrect	20	74	194	M	Right
Incorrect	41	71	165	M	Right
Incorrect	20	65	128	F	Right
Incorrect	22	72	178	M	Right
Incorrect	29	67	145	F	Left
Incorrect	33	62.25	130	F	Both
Incorrect	21	72	145	M	Left
Incorrect	38	73	212	M	Right
Incorrect	19	61	141	F	Right
Incorrect	20	74	190	M	Right

Incorrect	25	73	198	M	Right
Incorrect	19	73	175	M	Right
Incorrect	28	65	155	M	Left
Correct	20	65	185	F	Right
Correct	30	67	145	M	Right
Correct	20	63	145	M	Right
Correct	32	61	134	F	Right
Correct	19	70	185	F	Right
Correct	20	73	195	M	Right
Correct	42	68.5	210	F	Right
Correct	27	72	205	M	Right
Correct	20	71	155	M	Right
Correct	21	60	99	F	Right
Correct	47	70	190	M	Right
Correct	19	69	214	M	Right
Correct	21	71	188	M	Right
Correct	19	66	140	F	Right
Correct	23	68.75	132	M	Right
Correct	23	71	185	M	Right
Correct	37	68	165	M	Right
Correct	41	74	176	M	Right
Correct	21	60	111	F	Right
Correct	19	71	170	M	Right
Correct	20	72	170	M	Right
Correct	51	63	170	F	Right
Correct	18	60	100	F	Right

APPENDIX D: Raw Data for Analysis

Table 8: Bridge Right Data for analysis, these numbers were output from Matlab and used in Minitab software to perform the statistical analysis. The muscle activity is in mV. NT stands for "no tape" or the pre-tape condition, while T stands for "tape" or the post-tape condition.

Bridge Right Data			
Subject 1 NT	0.021236	Subject 1 T	0.021882
Subject 2 NT	0.191631	Subject 2 T	0.166465
Subject 3 NT	0.006586	Subject 3 T	0.006594
Subject 4 NT	0.020542	Subject 4 T	0.024125
Subject 5 NT	0.278139	Subject 5 T	0.199106
Subject 6 NT	0.053447	Subject 6 T	0.047195
Subject 7 NT	0.062262	Subject 7 T	0.081142
Subject 8 NT	0.031234	Subject 8 T	0.026573
Subject 9 NT	0.03943	Subject 9 T	0.04113
Subject 10 NT	0.01235	Subject 10 T	0.013509
Subject 11 NT	0.09893	Subject 11 T	0.08745
Subject 12 NT	0.050626	Subject 12 T	0.049293
Subject 13 NT	0.018886	Subject 13 T	0.016525
Subject 14 NT	0.047021	Subject 14 T	0.043159
Subject 15 NT	0.062589	Subject 15 T	0.059504
Subject 16 NT	0.053943	Subject 16 T	0.050015
Subject 17 NT	0.028073	Subject 17 T	0.027147
Subject 18 NT	0.038116	Subject 18 T	0.041912
Subject 19 NT	0.089672	Subject 19 T	0.081053
Subject 20 NT	0.048389	Subject 20 T	0.044315
Subject 21 NT	0.051513	Subject 21 T	0.050022
Subject 22 NT	0.032397	Subject 22 T	0.034065
Subject 23 NT	0.0191	Subject 23 T	0.025315
Subject 24 NT	0.314996	Subject 24 T	0.234183
Subject 26 NT	0.010469	Subject 26 T	0.011343
Subject 27 NT	0.080559	Subject 27 T	0.099124
Subject 28 NT	0.01771	Subject 28 T	0.020348
Subject 29 NT	0.048842	Subject 29 T	0.018618
Subject 30 NT	0.026909	Subject 30 T	0.030184
Subject 31 NT	0.082727	Subject 31 T	0.096095
Subject 32 NT	0.078541	Subject 32 T	0.070086
Subject 33 NT	0.050148	Subject 33 T	0.05009
Subject 34 NT	0.035591	Subject 34 T	0.042899
Subject 35 NT	0.023493	Subject 35 T	0.021791
Subject 36 NT	0.012039	Subject 36 T	0.011138
Subject 37 NT	0.030959	Subject 37 T	0.026839
Subject 38 NT	0.046643	Subject 38 T	0.056241

Subject 39 NT	0.070349	Subject 39 T	0.089539
Subject 40 NT	0.019092	Subject 40 T	0.018856
Subject 41 NT	0.049336	Subject 41 T	0.044248
Subject 42 NT	0.009261	Subject 42 T	0.010975
Subject 43 NT	0.011579	Subject 43 T	0.011017
Subject 44 NT	0.033536	Subject 44 T	0.024308
Subject 45 NT	0.040761	Subject 45 T	0.031232
Subject 46 NT	0.017566	Subject 46 T	0.017417
Subject 47 NT	0.060715	Subject 47 T	0.065657
Subject 48 NT	0.403432	Subject 48 T	0.403472
Subject 49 NT	0.041563	Subject 49 T	0.041525
Subject 50 NT	0.112495	Subject 50 T	0.120003

Table 9: Bridge Left data for analysis which is the output from Matlab. Only subjects which were analyzed for this exercise and side of the body are included in the table. The muscle activity is in mV. NT stands for "no tape" or the pre-tape condition, while T stands for "tape" or the post-tape condition.

Bridge Left Data			
Subject 2 NT	0.00429	Subject 2 T	0.00435
Subject 3 NT	0.004408	Subject 3 T	0.004654
Subject 4 NT	0.004995	Subject 4 T	0.009371
Subject 5 NT	0.004737	Subject 5 T	0.00404
Subject 6 NT	0.00492	Subject 6 T	0.004566
Subject 8 NT	0.004957	Subject 8 T	0.004811
Subject 13 NT	0.00575	Subject 13 T	0.004666
Subject 14 NT	0.004671	Subject 14 T	0.003186
Subject 16 NT	0.005171	Subject 16 T	0.004856
Subject 17 NT	0.004414	Subject 17 T	0.004465
Subject 18 NT	0.029356	Subject 18 T	0.006891
Subject 19 NT	0.007222	Subject 19 T	0.00461
Subject 20 NT	0.001372	Subject 20 T	0.001364
Subject 23 NT	0.004172	Subject 23 T	0.003913
Subject 26 NT	0.002664	Subject 26 T	0.003739
Subject 30 NT	0.004519	Subject 30 T	0.004416
Subject 31 NT	0.006907	Subject 31 T	0.005046
Subject 32 NT	0.002426	Subject 32 T	0.002257
Subject 33 NT	0.00504	Subject 33 T	0.004801
Subject 35 NT	0.001103	Subject 35 T	0.002744
Subject 38 NT	0.005274	Subject 38 T	0.005974
Subject 40 NT	0.005017	Subject 40 T	0.004374
Subject 47 NT	0.004312	Subject 47 T	0.00101

Table 10: Plank Right data output from Matlab for statistical analysis. Only usable data for this exercise is included in the table. The muscle activity is in mV. NT stands for "no tape" or the pre-tape condition, while T stands for "tape" or the post-tape condition.

Plank Right Data			
Subject 1 NT	0.004873	Subject 1 T	0.004448
Subject 3 NT	0.003825	Subject 3 T	0.002897
Subject 4 NT	0.006895	Subject 4 T	0.005934
Subject 5 NT	0.070223	Subject 5 T	0.056862
Subject 6 NT	0.011654	Subject 6 T	0.011548
Subject 7 NT	0.009941	Subject 7 T	0.012247
Subject 8 NT	0.006915	Subject 8 T	0.004839
Subject 9 NT	0.004334	Subject 9 T	0.003964
Subject 10 NT	0.005387	Subject 10 T	0.006671
Subject 11 NT	0.01746	Subject 11 T	0.023881
Subject 12 NT	0.007619	Subject 12 T	0.009778
Subject 13 NT	0.004699	Subject 13 T	0.005376
Subject 14 NT	0.012823	Subject 14 T	0.011262
Subject 15 NT	0.013783	Subject 15 T	0.014378
Subject 16 NT	0.007042	Subject 16 T	0.006769
Subject 17 NT	0.008075	Subject 17 T	0.006751
Subject 18 NT	0.034259	Subject 18 T	0.032931
Subject 19 NT	0.023089	Subject 19 T	0.024313
Subject 20 NT	0.008322	Subject 20 T	0.00782
Subject 21 NT	0.007371	Subject 21 T	0.009197
Subject 22 NT	0.018559	Subject 22 T	0.018419
Subject 23 NT	0.006902	Subject 23 T	0.00716
Subject 25 NT	0.006864	Subject 25 T	0.010852
Subject 26 NT	0.004525	Subject 26 T	0.006987
Subject 27 NT	0.013958	Subject 27 T	0.017718
Subject 28 NT	0.004907	Subject 28 T	0.005711
Subject 29 NT	0.014896	Subject 29 T	0.011757
Subject 30 NT	0.009431	Subject 30 T	0.011297
Subject 31 NT	0.011237	Subject 31 T	0.01195
Subject 32 NT	0.015663	Subject 32 T	0.016057
Subject 33 NT	0.006493	Subject 33 T	0.007188
Subject 35 NT	0.004365	Subject 35 T	0.005232
Subject 36 NT	0.007655	Subject 36 T	0.004411
Subject 37 NT	0.003269	Subject 37 T	0.003104
Subject 38 NT	0.008373	Subject 38 T	0.008348
Subject 39 NT	0.03823	Subject 39 T	0.03129
Subject 40 NT	0.007052	Subject 40 T	0.009832
Subject 41 NT	0.013372	Subject 41 T	0.011792
Subject 42 NT	0.002892	Subject 42 T	0.006424

Subject 43 NT	0.003449	Subject 43 T	0.004483
Subject 44 NT	0.007395	Subject 44 T	0.007484
Subject 45 NT	0.010276	Subject 45 T	0.008076
Subject 46 NT	0.007509	Subject 46 T	0.007055
Subject 47 NT	0.029046	Subject 47 T	0.034146
Subject 48 NT	0.049215	Subject 48 T	0.055891
Subject 49 NT	0.006192	Subject 49 T	0.007944
Subject 50 NT	0.02017	Subject 50 T	0.027292

Table 11: Plank Left data output from Matlab for use in statistical analysis using Minitab. Only those subjects with viable data for this exercise are included in the table. The muscle activity is in mV. NT stands for "no tape" or the pre-tape condition, while T stands for "tape" or the post-tape condition.

Plank Left Data			
Subject 3 NT	0.008964	Subject 3 T	0.008288
Subject 5 NT	0.005142	Subject 5 T	0.004572
Subject 6 NT	0.006749	Subject 6 T	0.006592
Subject 7 NT	0.005314	Subject 7 T	0.005591
Subject 13 NT	0.004588	Subject 13 T	0.005484
Subject 18 NT	0.005012	Subject 18 T	0.003761
Subject 20 NT	0.002311	Subject 20 T	0.001499
Subject 23 NT	0.005624	Subject 23 T	0.004009
Subject 26 NT	0.002632	Subject 26 T	0.002538
Subject 31 NT	0.00525	Subject 31 T	0.004824
Subject 32 NT	0.002315	Subject 32 T	0.002236
Subject 33 NT	0.004834	Subject 33 T	0.00999
Subject 35 NT	0.001111	Subject 35 T	0.01532
Subject 37 NT	0.004642	Subject 37 T	0.004502

Table 12: Superman Right data output from Matlab for use in statistical analysis using Minitab. Only those subjects with viable right side data for the Superman exercise are included in this table. The muscle activity is in mV. NT stands for "no tape" or the pre-tape condition, while T stands for "tape" or the post-tape condition.

Superman Right Data			
Subject 1 NT	0.074835	Subject 1 T	0.042622
Subject 2 NT	0.473896	Subject 2 T	0.361055
Subject 3 NT	0.016378	Subject 3 T	0.012778
Subject 4 NT	0.047503	Subject 4 T	0.05391
Subject 6 NT	0.079712	Subject 6 T	0.089565
Subject 7 NT	0.136635	Subject 7 T	0.189169
Subject 8 NT	0.064565	Subject 8 T	0.051233
Subject 9 NT	0.082276	Subject 9 T	0.089919
Subject 10 NT	0.034556	Subject 10 T	0.035609
Subject 11 NT	0.168669	Subject 11 T	0.187058

Subject 12 NT	0.105064	Subject 12 T	0.119627
Subject 13 NT	0.033258	Subject 13 T	0.02887
Subject 14 NT	0.114253	Subject 14 T	0.072392
Subject 15 NT	0.088418	Subject 15 T	0.094875
Subject 16 NT	0.078075	Subject 16 T	0.061643
Subject 17 NT	0.034321	Subject 17 T	0.030411
Subject 18 NT	0.155474	Subject 18 T	0.136701
Subject 19 NT	0.19627	Subject 19 T	0.163657
Subject 20 NT	0.073574	Subject 20 T	0.053425
Subject 21 NT	0.139464	Subject 21 T	0.162608
Subject 22 NT	0.056977	Subject 22 T	0.051508
Subject 23 NT	0.035896	Subject 23 T	0.035506
Subject 24 NT	0.224592	Subject 24 T	0.217032
Subject 25 NT	0.080047	Subject 25 T	0.108794
Subject 26 NT	0.020679	Subject 26 T	0.023383
Subject 27 NT	0.153848	Subject 27 T	0.206778
Subject 28 NT	0.033218	Subject 28 T	0.028147
Subject 29 NT	0.115328	Subject 29 T	0.062795
Subject 30 NT	0.077182	Subject 30 T	0.085203
Subject 31 NT	0.181786	Subject 31 T	0.146668
Subject 32 NT	0.13245	Subject 32 T	0.135774
Subject 33 NT	0.090093	Subject 33 T	0.10073
Subject 34 NT	0.063374	Subject 34 T	0.081598
Subject 35 NT	0.042289	Subject 35 T	0.042685
Subject 36 NT	0.023467	Subject 36 T	0.02064
Subject 37 NT	0.060109	Subject 37 T	0.04884
Subject 38 NT	0.081314	Subject 38 T	0.088981
Subject 39 NT	0.204676	Subject 39 T	0.190599
Subject 40 NT	0.019226	Subject 40 T	0.026975
Subject 41 NT	0.069415	Subject 41 T	0.063641
Subject 42 NT	0.013067	Subject 42 T	0.019861
Subject 43 NT	0.024447	Subject 43 T	0.028738
Subject 44 NT	0.078311	Subject 44 T	0.053216
Subject 45 NT	0.089891	Subject 45 T	0.073057
Subject 46 NT	0.029112	Subject 46 T	0.024385
Subject 47 NT	0.117208	Subject 47 T	0.112553
Subject 48 NT	0.735736	Subject 48 T	0.716746
Subject 49 NT	0.094843	Subject 49 T	0.093989
Subject 50 NT	0.264767	Subject 50 T	0.208346

Table 13: Superman Left data output from Matlab for use in statistical analysis in Minitab software. Only those subjects which had viable left side data for Superman exercise were included in this table. The muscle activity is in mV. NT stands for "no tape" or the pre-tape condition, while T stands for "tape" or the post-tape condition.

Superman Left Data			
Subject 2 NT	0.014568	Subject 2 T	0.006574
Subject 3 NT	0.004132	Subject 3 T	0.006722
Subject 4 NT	0.004848	Subject 4 T	0.006374
Subject 5 NT	0.005086	Subject 5 T	0.004385
Subject 6 NT	0.006295	Subject 6 T	0.00484
Subject 7 NT	0.004991	Subject 7 T	0.00589
Subject 13 NT	0.004842	Subject 13 T	0.004579
Subject 14 NT	0.005594	Subject 14 T	0.003387
Subject 15 NT	0.005015	Subject 15 T	0.00631
Subject 16 NT	0.005107	Subject 16 T	0.004908
Subject 17 NT	0.006659	Subject 17 T	0.005771
Subject 18 NT	0.004066	Subject 18 T	0.003737
Subject 20 NT	0.002438	Subject 20 T	0.001011
Subject 23 NT	0.003988	Subject 23 T	0.00377
Subject 24 NT	0.006167	Subject 24 T	0.004406
Subject 26 NT	0.002608	Subject 26 T	0.002343
Subject 30 NT	0.004652	Subject 30 T	0.004481
Subject 31 NT	0.005787	Subject 31 T	0.01304
Subject 32 NT	0.002729	Subject 32 T	0.004422
Subject 35 NT	0.001461	Subject 35 T	0.003611
Subject 37 NT	0.005838	Subject 37 T	0.00703
Subject 40 NT	0.004479	Subject 40 T	0.008937
Subject 47 NT	0.005165	Subject 47 T	0.00555