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*Original Article*

# Muscle activation pattern of gluteus medius, tibialis anterior and peroneus longus during drop landing on different surfaces: a cross-sectional study

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## Abstract

**Background:** Gluteus medius (GMeds), peroneus longus (PL), and tibialis anterior (TA) help in maintaining frontal stability of the lower extremity, particularly, the ankle. Muscle activation must be sufficient to prevent the occurrence of an ankle sprain. The purpose of this study is to compare the muscle activation of the GMeds, TA, and PL during drop landing on stable and unstable surfaces of physically active individuals. **Methods:** Surface EMG (sEMG) was used to determine the muscle activation pattern of the GMeds, TA, and PL of fifteen (15) recreational athletes during drop landing. The mean percentage of maximum voluntary isometric contraction (%MVIC) was calculated for comparison. Wilcoxon signed-rank test was used to compare means. **Results:** There were no statistically significant differences in the muscle activity of GMeds ($p=0.69$), TA ($p=0.26$), and PL ($p=0.23$) on stable and unstable surfaces. However, a small effect size showed that GMeds ($d=0.30$) has higher activation in the unstable surface while TA ($d=0.28$) and PL ($d=0.17$) have lower activation on unstable surface. **Conclusion**: Landing surface does not significantly alter muscle activity of GMeds, TA, and PL. However, the magnitude of the difference in the mean %MVIC between groups shows the compensatory mechanism of the body when subjected to different surface conditions. This can be used when creating injury prevention programs of the lower extremity.

***Keywords***: *gluteus medius, tibialis anterior, peroneus longus, muscle activation, landing*

## INTRODUCTION

Landing is commonly performed in human locomotion[1,2] especially in sports. Drop landing is an isolated landing with no subsequent motion.[3] Examples include a gymnast performing a dismount, landing after a rebound of a basketball player, or landing of a volleyball player after spiking the ball.[3-6] This plays an important role in successful sports performance[7,8] for it reduces the total body momentum, absorbs impact load, and prevents injuries.[9,10] It is also where most injuries, such as ankle sprain, occur.

In sports, landing occurs on stable and unstable surfaces.[11] The latter is defined as any surface that is unsteady, not fixed or not firm.[12] This can include trampolines, wobble boards[13], foam[11], and BOSU ball.[14] Unstable surfaces are as equally important to be considered as stable surfaces due to the modifications of musculoskeletal loading in response to changing surfaces.[10] Due to large loads absorbed by the musculoskeletal system upon landing, strategies to reduce and control the reaction force must be initiated before impact.[10] Strategies including muscle activation and segment kinematics before landing require synergistic work[10,15] by multiple muscles and segments of the lower extremity specifically the hip and ankle[16,17] to work in synergy. The muscle activation pattern of the lower extremity during drop landing works for absorbing the stress of the impact of landing and stabilization of the lower extremities to avoid injuries.[3,5] Improved muscle activation can provide stability, thus decreasing the risk for injury to occur during landing.[6,8,18-21]

There is a relationship between the proximal and distal joints of our lower extremity.[16,17] Following the kinetic linking, ankle invertors, evertors, and GMeds are responsible for movements and stability in the frontal plane of the ankle joint. If either the hip or the ankle presents with a problem, the other is affected as well. One study investigated the pre-fatigue and post-fatigue muscle activation pattern of the GMeds, ankle evertors, and invertors during a lateral hop in individuals with or without chronic ankle instability (CAI). It showed proximal and distal muscle alteration in patients with CAI which is attributed to a centralized feedforward mechanism developed from repetitive ankle injuries.[22] There were also studies on the effects of chronic ankle sprain and functional instability on the activities of the TA, PL, gastrocnemius lateralis, rectus femoris, vastus lateralis, and bicep femoris. These reported alteration in patterns of muscular activation of these muscles during landing, thereby increasing the risk of re-injury of people with chronic ankle sprain.[6,19]

Most studies on muscle activation of GMeds were done in either single-leg landings or lateral hops.[21-23] Several studies used force plates also to gather the force generated by the muscles. Landing on a stable surface is also common in the literature. To the researchers' knowledge, there is no study yet that thoroughly discussed the muscle activation of frontal plane muscles such as GMeds, TA, and PL during double leg drop landing on stable and unstable surfaces.

The purpose of this study is to compare the muscle activation pattern of the GMeds, TA, and PL during drop landing on stable and unstable surfaces. This study can establish a baseline in muscle activation pattern and future research for the prevention of ankle sprain.

## METHODOLOGY

**Research Design.** This is a cross-sectional study design that compared the mean percentage of muscle activation of the GMeds, TA, and PL of physically active individuals during drop landing on stable and unstable surfaces.

**Participants.** The sample size was based on the study conducted by Ambegaonkar, et.al.[3] Fifteen (15) physically active individuals within the age group of 18 - 25 years old[24] from the University of Santo Tomas participated in the study. Physically active male or female individuals who participate in aerobic or anaerobic exercises for at least 1.5 – 3 hours a week were included in the study. An individual is excluded from the study if he/she is a competitive athlete since they undergo extensive training and participate in competitive physical activities or sports/games which require physical strength, agility, or stamina.[25] These could all affect the data. The recruitment was administered in Room 134 at St. Martin de Porres Building, University of Santo Tomas.

A self-made screening tool was used to determine the age and to classify whether they were competitive athletes or not. The face validity of the tool was done by showing it to professionals and ten (10) random individuals to check if the tool was clear and valid.

Physical Activity Readiness Questionnaire for Everyone (2018 PAR-Q+) was used to determine the inclusion of the participant in the study. The previous and current health conditions of the participants were determined using the same tool in the study. This tool has an exceptionally good (r=0.99) reliability.[26]

**Outcome Measure.** Surface electromyography (sEMG) using the Trigno™ Surface EMG System by Delsys®. was used to gather the muscle activation pattern of GMeds, TA, and PL muscles.[27] Muscle activation was calculated as a percentage of maximum voluntary isometric contraction (%MVIC). This allows the assessment of the level of muscle activity of the task compared to the maximum activation capacity of the muscle. According to a study by Benesch et.al[28] which used EMG as a measurement tool for peroneal muscles, the coefficient of correlation (Spearman's rho) between the peroneus brevis and days 1-5 was 0.67 (p=0.18) and for the PL 0.00 (p>0.999).

### Procedures

*Reliability Testing Phase.* Before the actual data gathering, an interrater reliability testing was done for the two assessors to ensure proper placement of electrodes on the muscle of the subjects. The assessors made three (3) trials measuring the anatomical landmarks in millimeters based on the SENIAM protocol. These were done on ten (10) random people.

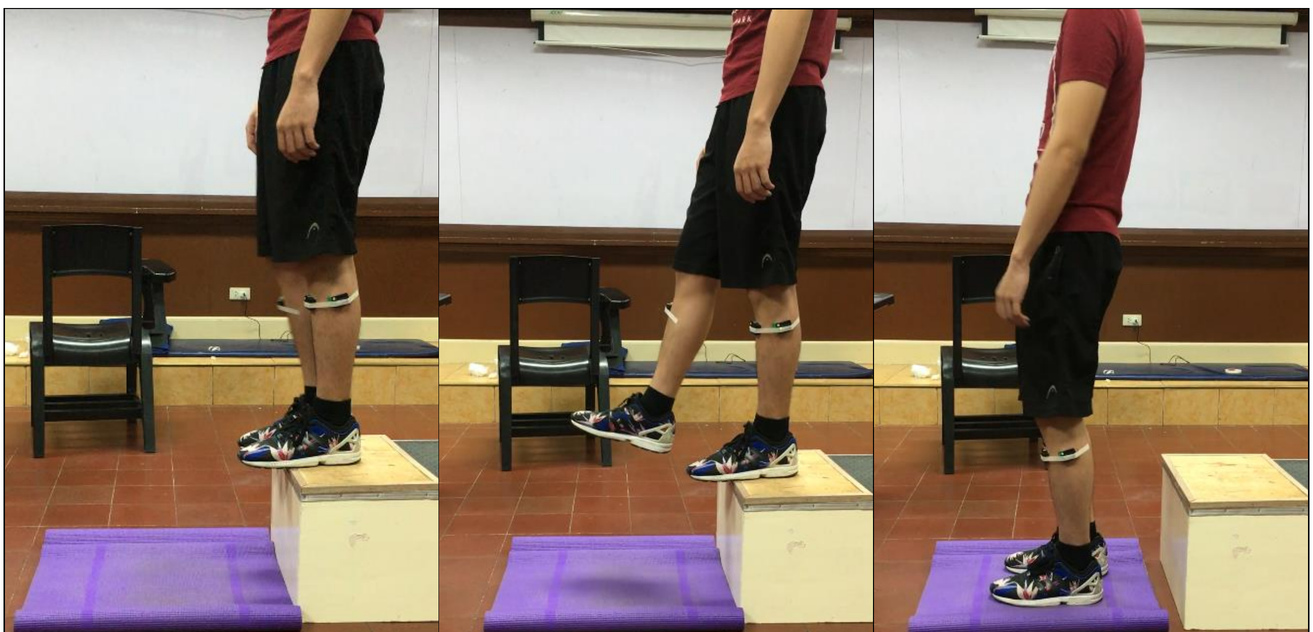
*Recruitment Phase.* After obtaining ethical approval from the University of Santo Tomas College of Rehabilitation Sciences – Ethics Review Committee, the researchers recruited participants using flyers, word of mouth, and social media platforms. Participants completed a self-made screening tool and the 2018 PAR-Q+ that determined their eligibility for the study.

**Data Gathering.** The participants were informed to wear cycling shorts, a shirt, and rubber shoes. The informed consent form was presented and explained by the assessors and the participants were asked to read and voluntarily sign the form. The assessors oriented the participants of the flow of the study.

The correct drop-landing was demonstrated by one of the assessors (See Figure 1).

Adhesive tape was applied to the EMG surface electrodes for added security.

After electrode placement, participants were asked to perform three (3) trials of maximum voluntary isometric contractions (MVIC) lasting for 3 seconds each with 30-second rest in-between trials on GMeds, TA, and PL. The MVIC served as the baseline to where the EMG activities during tasks were compared to. During the MVIC of the GMeds, the participant was asked to abduct the leg against the wall. A goniometer was used to ensure that the leg is in 25˚ of abduction.[29] For the PL, the participant everted the ankle while the assessor applied manual resistance.[30] For the TA, the participant inverted the ankle in dorsiflexion while the assessor applied manual resistance.[30] The PL and TA measurements were done in a sitting position. After the MVIC measurement, the participants were given a minute rest before the actual performance of the drop landing. The participants stood on a 30 cm high platform and were asked to perform the drop landing on a cemented stable surface or a rubber mat.



| Starting position | Initiation of drop landing | Final position of drop landing |
|---|---|---|

**Figure 1.** Drop-landing technique.

Participants were asked to perform three trials until drop-landings were performed properly. The areas of the skin to be tested were cleaned with isopropyl rubbing alcohol. The electrodes were placed overlying the muscle bellies of the Gmeds, TA, and PL (See Table 1 for landmarks).

The rubber mat was made of a non-slid material and was one-fourth of an inch high.

**Table 1.** Summary of electrode placement and participant position.

| Muscle | Anatomical landmarks and reference line | Position of locating the anatomical landmarks |
|---|---|---|
| **Gluteus medius** | The percentage distance of 33.4 ± 12.8% from the iliac crest to the greater trochanter, starting from the greater trochanter (Rainoldi, et. al., 2004) | Sidelying |
| **Tibialis Anterior** | The percentage difference of 15.5 ± 4.2% from the tuberosity of tibia to the inter-malleoli line, starting from the tuberosity of tibia (Rainoldi, et. al., 2004) | Short sitting |
| **Peroneus Longus** | The percentage distance of 17 ± 4% from the head of fibula to the lateral malleolus, starting from the head of fibula. (Rainoldi, et. al., 2004) | Short sitting |

Randomization using a flip coin method was used to determine the sequence of the landing surface. The sequence was determined as unstable, unstable, stable, stable, unstable, and ending on a stable surface. This was done to lessen the learning effect. Three trials[11] were done, and each trial was documented using a smartphone simultaneously with sEMG. This enabled the researchers to synchronize the time of initial contact with EMG activity.

**Data Analysis.** Multiple raters consistency, a two-way mixed-effects model of intraclass correlation coefficient was used to determine the interrater reliability of the electrode placement.

EMG signals were calculated using EMGWork Analysis software version 4 by Delsys®. Amplitude Analysis script was run at a Root Mean Square(RMS) window length of 0.125 seconds with RMS window overlap of 0.0625 seconds to normalize the data and get the %MVIC. The %MVIC value corresponding to the time of initial contact of the foot upon landing was recorded.

Data were presented as group means ± standard deviations (SD) per muscle for each surface. The percentage of MVIC for each trial was computed. Wilcoxon Signed-Rank Test was used to analyze the difference in the muscle activation of the three muscles during drop landing on stable and unstable surfaces. The degree of difference between the two groups was determined using the effect size. The level of significance was set to $\alpha = 0.05$.

## RESULTS

Initially, forty (40) participants were recruited in the study. Out of the 40, nineteen (19) met the inclusion criteria. One of the participants backed out and three (3) did not respond to researchers after being contacted. A total of fifteen (15) participants proceeded with the study.

There were ten (10) males and (5) females with the mean age of 19.67 ± 1.6 years old. The mean height is 165.3 ± 10 cm and the mean weight is 64.95 ± 13.49 kg. There were no statistically significant differences in the age, height, and weight variables of the participants ($p > 0.05$). This means that the participants are homogenous at baseline.

**Reliability Testing**. There was an excellent agreement between the two assessors on the electrode placement measurement of GMeds (ICC= 0.97), TA (ICC = 0.98), and PL (ICC= 0.86). There was no significant difference noted on the measurement of the landmark for electrode placement of any of the three muscles among the assessors.

**Table 2**. Mean and standard deviation for GMeds, TA and PL electrode placement.

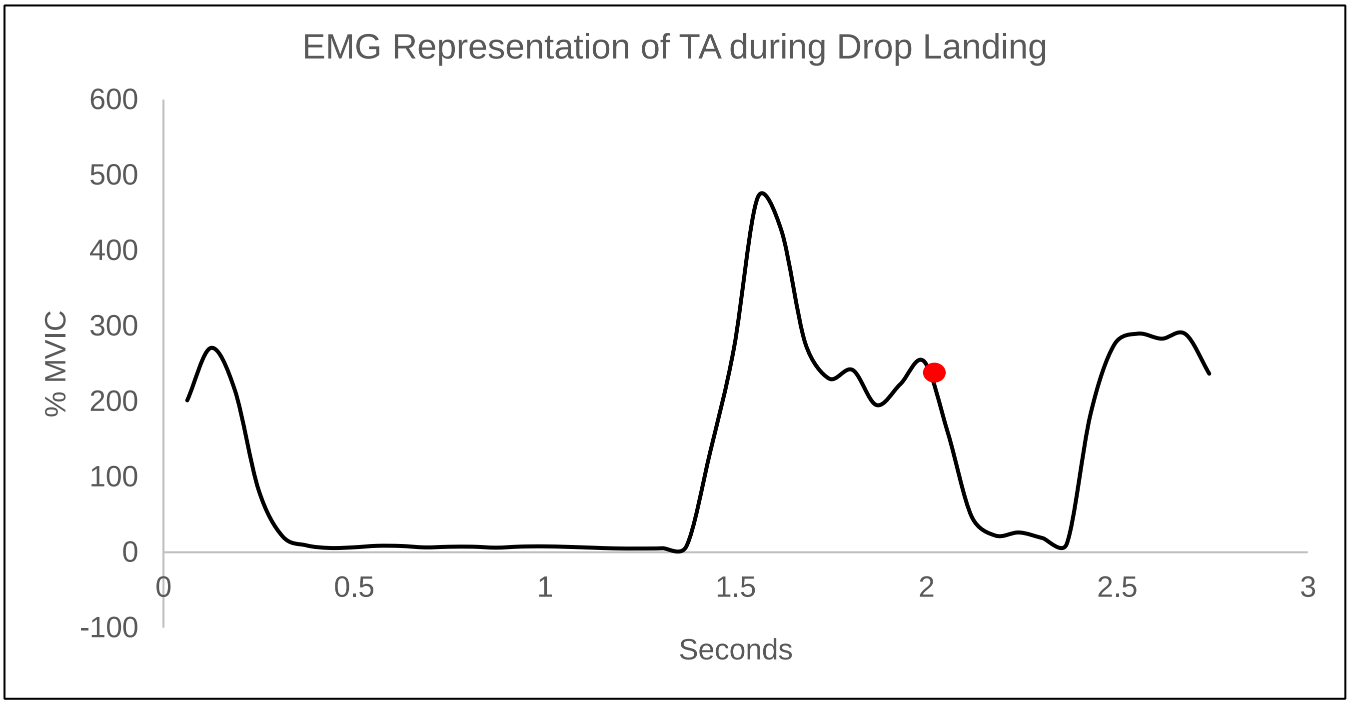
| Muscle | Mean ± SD (in cm) | | P value |
|---|---|---|---|
| | RATER A (n=10) | RATER B (n=10) | |
| GMeds | 38.53 ± 3.5 | 38.86 ± 3.93 | 0.62 |
| TA | 47.48 ± 4.57 | 47. 95 ± 4.78 | 0.65 |
| PL | 56.57 ± 5.51 | 56.29 ± 5.16 | 0.73 |

**EMG Analysis.** Figure 2 shows a representative EMG taken during the initial contact of the participant. The red dot marks the normalized %MVIC of TA at the initial contact of the foot on the surface.

Table 3 shows the summary of the %MVIC of the GMeds, TA, and PL during the initial contact of drop landing.

Results showed that there were no statistically significant differences in the muscle of GMeds, TA, and PL ($p > 0.05$) on both landings on a stable and unstable surface. However, the mean % MVIC of the GMeds is higher on the unstable surface while the %MVIC of the TA and PL are both higher in the stable surface. Small effect size was seen in both the GMeds and TA activation.

In the stable surface, the TA had the highest activation, followed by the PL and then the GMeds. In the unstable surface, the GMeds exhibited the highest %MVIC, followed by the PL and then the TA.




**Legend:** ●- initial contact

**Figure 3.** Sample normalized EMG of TA during drop landing

**Table 4.** Percentage of MVIC during stable and unstable surface drop landing.

| Muscles | Mean ± SD | | p-value | Effect size | CI (95%) |
|---|---|---|---|---|---|
| | Stable Surface | Unstable Surface | | | |
| GMeds | 29.46 ± 19.89 | 52.83 ± 105.01 | 0.69 | 0.30 | -1.03,0.42 |
| TA | 72.54 ± 121.76 | 44.06 ± 63.61 | 0.26 | 0.28 | -0.44,1.01 |
| PL | 58.03 ± 69.33 | 47.83 ± 42.95 | 0.23 | 0.17 | -0.05,0.89 |

## DISCUSSION

The primary findings of our study are as follows: (1) there was no significant difference between the EMG findings of the three muscles during drop landing on stable and unstable surfaces; (2) the mean %MVIC activation of the GMeds is higher on an unstable surface; and (3) the mean %MVIC activation of TA and PL was lower on an unstable surface.

Muscle activation on the initial contact during drop landing is important in reducing the total body momentum, absorbing impact load, and stabilizing the lower extremity to prevent injuries. The GMeds, TAs, and PL can stabilize the hip and ankle[10,15] and prevent possible injuries[3] such as ankle sprain.

Many sports take place on unstable surfaces[11] which increases the need for necessary body modifications to minimize the reaction force before impact.[10] The GMeds controls the frontal plane stability by generating an abductor torque. The PL, with the TA, stabilizes the subtalar joint and prevents excessive rotation to maintain balance during landing. The increased activation of GMeds on an unstable surface can be due to the increased demand for stability. The increased activation is needed to make the lower limb stable and in proper position upon landing and to prevent the excessive frontal plane destabilization brought about by the instability of the surface. Activation of the GMeds will prevent the knee collapsing in valgus and thus preventing injuries.

The decreased activation of TA and PL coincides with the findings of several studies that reported decreased muscle activity also of these muscles during landing on an unstable surface.[31,32] In a study that investigated the effect on the force output and muscle activity when subjected to different surface conditions during isometric squats, it showed that there was a significantly lower muscle activity when isometric squat was performed on an unstable surface compared to a stable surface. Furthermore, the same study showed that squatting on an unstable surface has equal or less benefit to improving or maximizing muscle activity during resistance training due to significantly lower muscle activity.[31] In a more recent study, the effects of surface instability on neuromuscular activation of leg muscles during drop jumps have been examined and results showed that increasing surface instability decreases muscle activity.[32] Another study investigated the effects of surface instability on muscle activity of leg muscles during drop jumps and landings. Results showed decreased muscle activity of the lower extremity during the pre-activation phases of the drop jumps and landings when performed on an unstable surface.[11]

Decreased lower extremity muscle activity in the TA and PL can be treated as a modified feedforward mechanism[11] of the body for the unstable surface. The central nervous system adjusts the mechanical properties of the musculoskeletal system following the needs of the body. During voluntary landing, the muscle can alter itself from being spring to a damping unit.[9] A highly stiff muscle will make it difficult and even impossible to absorb the ground reaction force. Meaning the decreased muscle activity can be associated with joint stiffness regulation to modify for lower impact stress, caused by the damping of the landing as a preventive measure.[9,11] However, the decreased activity of the TA and PL during landing may cause a considerably greater amount of force that will be absorbed by the knee. This can also cause alteration in the muscle firing on proximal muscles as an adaptation. If not rehabilitated, these can pose an additional injury risk.

## CONCLUSION

Landing on an unstable and stable surface yields no statistically significant differences in the muscle activation pattern of GMeds, TA, and PL. However, the mean %MVIC of GMeds activation is higher, while the mean %MVIC of TA and PL are lower on an unstable surface. The high GMeds activation on an unstable surface can be a compensatory mechanism to maintain stability on the lower extremity on landing, while the decreased activity of the TA and PLs can be the neural mechanism of the body in absorbing the high impact force on the initial contact in landing. Future studies may investigate the muscle activity of these muscles on patients with chronic ankle sprain. Since this study showed the decrease in muscle activity on an unstable surface, it is suggested that future studies investigate this on patients with chronic ankle sprain whose muscle activity may have decreased also. This can help clinicians change their approach in ankle rehabilitation.

**Implication.** This study showed that an unstable surface may not elicit a considerably high amount of muscle activation on the ankle joint which initially absorbs the impact on initial contact in landing. The use of unstable surfaces such as BOSU Ball and foam mats during exercises that promote and increase ankle stability through co-activation of the frontal plane muscles may not be recommended in preventing ankle injuries. The use of the unstable surface for increasing proprioception of the ankle may be considered but not when the purpose is to increase ankle stabilization. Stable surfaces are still preferred.

**Limitation.** The study is not without limitations. First, the small sample decreases the power and the generalizability of the results to the population. Second, the thickness of the unstable surface may play a big factor in the results. The variability of the results of muscle activity in an unstable surface in the literature may be due to methodological differences especially on the type of unstable surface used. Third, the kind of exercises that the participants engaged in were not elaborated thus the difference in muscle strength of each participant was not taken into consideration.

**Recommendation.** In line with the limitations of this study, few recommendations have been made for the continuing studies. First, the electrode placement should be guided by a musculoskeletal ultrasound to locate the muscle bellies accurately. The unstable surface that would be used should be thicker compared to the one used in this study to put the body in a more unstable environment. Also, consider the lower extremity exercise regimen of the participants to ensure that this will not affect the result of the EMG muscle activation pattern.

## Individual Author's Contributions

K.S, K.D; Designed and performed experiments, analyzed data and co-wrote the paper, supervised the research; R.S, S.A, S.C, R.D, R, E, I. F, A.G, L.S; Performed the experiment, analyzed the data and co-wrote the paper.

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## Conflicts of Interest

The authors of this paper declare no conflicting interest.

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