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# Effects of Different Types of Isometric Hip Contraction on Gluteus Medius and Tensor Fasciae Latae Activity During Squat Exercises

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## Abstract

Hip muscle activation and strengthening exercise programs are often used to prevent and treat various lower extremity injuries. Common exercise programs include squat exercises. The purposes of this study were to investigate gluteus medius (GMED) and tensor fasciae latae (TFL) muscle activity, and to assess the GMED/TFL ratio during squat exercises involving different isometric hip contraction conditions. Different types of isometric hip contraction were standard squat without hip contraction, squats with isometric hip adduction, and squats with isometric hip abduction. Twenty (10 males and 10 females) healthy subjects (23.7±2.8 years old) were recruited. Subjects performed the squat exercises with the back supported by a wall and knees flexed to 60°. Surface electromyography (EMG) was used to measure GMED and TFL activity. One-way repeated analysis of variance was used to compare GMED and TFL muscle activity and the GMED/TFL ratio. GMED and TFL EMG activity was significantly higher during squats with isometric hip adduction and abduction compared with the standard squat without hip contraction ($p<.05$). Between the isometric hip adduction and abduction contraction conditions, only the TFL EMG activity was significantly higher during squats with isometric hip adduction than isometric hip abduction ($p<.05$). The GMED/TFL ratio was significantly higher during squats with isometric hip adduction than isometric hip abduction ($p<.05$). Squats with isometric hip adduction and abduction improved GMED and TFL muscle activity. Furthermore, the GMED/TFL ratio was higher during isometric hip adduction than isometric hip abduction. Our data indicate that squat exercises involving isometric hip adduction enhance GMED muscle activity.

**Key Words:** Gluteus medius; Tensor fasciae latae; Squat.

## Introduction

Lower limb training regimens can be used to treat various lower limb dysfunctions (Powers, 2010). Lower limb injury prevention and rehabilitation programs often involve exercises with varying degrees of difficulty to target the gluteal muscles, engagement of which is essential for knee rehabilitation (Distefano et al, 2009; Powers, 2010). Several studies indicate an association between gluteal muscle weakness and knee injuries (Leetun et al, 2004; Nadler et al, 2000; Niemuth et al, 2005). Gluteal muscle weakness diminishes hip adduction and internal rotation control. Powers (2010) reported when the subjects with gluteal muscle weakness performed physical activity, knee valgus movements increased, leading to stress in the patellofemoral joint and iliotibial band (ITB); awareness of the interdependence of the hip and knee is important. There is growing evidence that gluteal muscle strengthening programs should be considered for the management of patellofemoral pain and ITB friction syndrome (Beers et al, 2008;

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Fredericson et al, 2000; Khayambashi et al, 2012). Fredericson et al (2000) and Beers et al (2008) reported that the hip abductor strengthening decreased the symptoms of ITB friction syndrome. Furthermore, the hip abductor strengthening was effective in improving the patellofemoral pain syndrome (Khayambashi et al, 2008).

Several knee rehabilitation and training programs incorporate the squat exercise (Barton et al, 2014), which can confer benefits for patellofemoral pain syndrome, ITB friction syndrome, and other hip, knee, and ankle dysfunctions. When properly administered, the squat exercise promotes lower limb and gluteal muscle strength. In addition, the movement that characterizes the squat exercise replicates functional activities such as traversing stairs, the transition from sitting to standing, and running and jumping (Baffa et al, 2012; Barton et al, 2014; Felício et al, 2011). Therefore, interest in the rehabilitative potential of the squat exercise is increasing.

In several previous studies the squat exercise has been used to target the vastus medialis and vastus lateralis muscles, which act synergistically to stabilize the patella (Coqueiro et al, 2005; Hertel et al, 2004; Irish et al, 2010). Decreased vastus medialis muscle activity leads to patella maltracking (Irish et al, 2010). The hip abductor muscles are considered important for patella tracking because they control internal rotation of the femur during functional and daily activities (Dierks et al, 2008; Powers, 2003); medial rotation of the femur increases the Q-angle (i.e., the angle formed by lines drawn from the anterior superior iliac spine through the center of the patella and from the center of the patella to the center of the tibial tubercle), thereby altering the degree of patella tracking (Powers, 2003). While the gluteus medius (GMED) and tensor fasciae latae (TFL) are the synergist muscles of the hip abduction, the posterior part of GMED acts as an hip external rotator, and the TFL acts as an hip internal rotator. In particular, weakness in the GMED can lead to increases in the Q-angle and various lower limb injuries and excessive TFL activation (Fredericson et al, 2000). The GMED also stabilizes the pelvis and lower limbs and is therefore relevant to the squat exercises.

Squat exercises have been incorporated strengthening of the entire lower limb including the gluteal muscle (Barton et al, 2014). Felício et al (2011) reported greater GMED muscle activity during squat exercises with isometric hip adduction and abduction contraction compared with the conventional squat exercise. However, previous studies are limited by their failure to evaluate TFL (an abductor and internal rotator of the hip) muscle activity during squat exercises; the TFL can exert lateral force on the patella. In addition, excessive hip internal rotation and lateral patellar tracking may lead to patellofemoral pain (Dierks et al, 2008; Souza and Powers, 2009; Willson et al, 2011). Therefore, it would be necessary to promote activity of the GMED while minimizing recruitment of the TFL.

For this reason, this study investigated GMED and TFL muscle activity, and assessed the GMED/TFL ratio, during squat exercises involving different types of isometric hip contraction (i.e., standard squats without hip contraction and squats involving isometric hip adduction or abduction). The purpose of this study was which type would best activate the GMED muscle activity while minimizing TFL muscle activity. We hypothesized that GMED and TFL muscle activity would increase during isometric hip adduction and abduction, and the GMED/TFL ratio would increase during adduction, but decrease during abduction.

## Methods

### Subjects

The sample size was calculated, based on pilot study data, using the G*power software ver. 3.1.5 (Franz Faul, University of Kiel, Kiel, Germany). A required sample size of five was confirmed with an effect size of .72, alpha level of .05, and power of

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.80. Therefore, 20 healthy subjects (10 males and 10 females) were recruited (Table 1). The inclusion criteria were no history of knee lesions or knee or lower limb surgery (Baffa et al, 2012), and no current knee pain (Felício et al, 2011). The exclusion criteria were any musculoskeletal disorder of the lower limbs, neurological or cardiopulmonary diseases (Selkowitz et al, 2013), and complaints of pain during any type of physical activity (Felício et al, 2011). Prior to the experiment, the examiner explained the entire procedure to all subjects, who provided written informed consent. The study was approved by the Yonsei University Wonju Institutional Review Board (approval number: 1041849-201412-BM-060-01).

### Instruments

Surface electromyography (EMG) (Noraxon TeleMyo DTS, Noraxon Inc., AZ, USA) was used to measure muscle activity on the dominant side (i.e., the side used when kicking a ball; Jacobs et al, 2005; Selkowitz et al, 2013; Yoon and Kim, 2014). Disposable, self-adhesive Ag/AgCl surface electrodes were placed at locations 2 ㎝ apart over each muscle (parallel to muscle fiber orientation). The GMED muscle comprises anterior, middle, and posterior sections. We measured activity in the posterior section because its function opposes that of the TFL muscle in the transverse plane, in which the posterior GMED acts as an external, and the TFL as an internal, hip rotator. For the GMED, electrodes were placed over the proximal section one-third of the distance between a mark on the posterior ilium and the greater trochanter. The posterior ilium landmark was 20% of the distance between the iliac crest and the L4~L5 interspace (O'Dwyer et al, 2011). For the TFL, electrodes were placed approximately 2 ㎝ below the anterior superior iliac spine (Criswell, 2011). Before attaching electrodes to the GMED and TFL muscles, skin was shaved and swabbed with alcohol cotton to reduce resistance. Following electrode attachment, EMG data were recorded using the Myo-Research Master Edition XP software package ver. 1.06 (Noraxon Inc., AZ, USA). EMG signals were sampled at 1,000 ㎐; the raw signal was filtered using a bandpass filter (Lancosh FIR) between 20 and 450 ㎐, and a 60 ㎐ notch filter was used to diminish electrical noise. EMG data were processed using root mean square values.

**Table 1.** General characteristics of subjects (N=20)

| Variables | Mean±SD[a] |
|---|---|
| Age (year) | 23.7±2.8 |
| Height (㎝) | 168.1±7.5 |
| Weight (㎏) | 61.5±10.3 |
| BMI[b](㎏/㎠) | 21.6±2.2 |

[a]mean±standard deviation, [b]body mass index.

### Electromyographic data collection

For normalization, 5-s maximal voluntary isometric contraction (MVIC) was calculated for each muscle to establish a basis for EMG signal amplitude normalization. MVIC for both the GMED and TFL muscles was performed against gravity and manual resistance using standard methods (Kendall et al, 2005). For the GMED, subjects were positioned in a side-lying position with the dominant leg raised and the bottom hip at a flexion angle of 45° and the knee at 90°, to improve stability. The dominant leg was abducted to approximately 50% of hip abduction; hip extensions with marginal lateral rotation were then performed. The examiner applied downward force to the ankle while maintaining the hip position with the other hand. For the TFL, subjects were placed in a supine position with the hip of the dominant side flexed and slight medial rotation commensurate with knee extension. The examiner applied downward force to the ankle in the direction of the hip extension. EMG activity recorded between 2~4 seconds was used to determine mean MVIC amplitude. Normalized muscle activity was presented as a percentage of MVIC.

### Procedures

All subjects were familiarized with the correct performance of the various squat exercises, which were each performed three times with a 30-s rest period between repetitions, and a 2-min rest period between conditions, to minimize muscle fatigue (Koh et al, 2011). All squats were performed with an additional load of 25% of each subject's body weight, contained within a backpack held over the thorax (Baffa et al, 2012). This load was identified as the minimal weight capable of intensifying myoelectric activity, particularly in the GMED (Robinson and Nee, 2007). Subjects performed squat exercises in standard and isometric hip adduction and abduction conditions with 60° knee flexion, while maintaining vertical alignment of the knees and toes (Escamilla et al, 2009). The 60° knee flexion was selected because Tang et al (2001) reported that greatest activation of the vastus medialis oblique muscle was achieved at 60° knee flexion during squat exercise, so it is optimal knee flexion angle for management of patellofemoral pain syndrome. The order of conditions was randomized by drawing lots. The examiner used a goniometer to confirm 60° knee flexion, following which subjects reached for their patellae along the target bar (positioned at a point equivalent to 60° knee flexion). To prevent compensatory knee motion, subjects aligned their heels and big toes directly on a tape measure and perpendicular to the target bar; during the exercises, their patellae contacted the target bar (O'Shea and Grafton, 2013).

### Standard squat without hip contraction

While in a standing position, subjects positioned themselves such that their backs were supported against the wall at least they could perform the squat exercise with feet shoulder-width apart (Baffa et al, 2012); they then moved downward over a 2-s period until the knees were flexed to 60° (Figure 1A). This position was maintained for 5 s following which subjects returned to the starting position over the course of a further 2 s (Barton et al, 2014). EMG activity between seconds 2∼4 s of the maintenance phase was collected and compared between the isometric hip adduction and abduction contraction conditions.

### Squat exercise with isometric hip adduction contraction

An identical position and procedure was used per the standard squat, but maximal isometric hip adduction contraction was effected using a soccer ball (22-㎝ diameter, 410 g) positioned between the medial femoral epicondyles during the 5-s maintenance phase (Boling et al, 2006) (Figure 1B).

### Squat exercise with isometric hip abduction contraction

An identical position and procedure was used per the standard squat, but maximal isometric hip abduction contraction was effected using a non-elastic band (OMPT Manual Belt, COREBODY, Namyangju, Korea) during the 5-s maintenance phase. The non-elastic band was positioned at the level of the lateral femoral epicondyles (Felício et al, 2011) (Figure 1C).

### Statistical analysis

A one-sample Kolmogorov-Smirnov test was used to assess normality of distribution; all variables were confirmed as normally distributed such that parametric tests were then applied. One-way repeated measures analysis of variance was performed to compare GMED and TFL muscle activity, and the GMED/TFL ratio, among the three hip contraction conditions. Bonferroni correction was used to determine differences among the squat exercises (.05/3=.017). Statistical analyses were performed using the SPSS ver. 21.0 (SPSS Inc., Chicago, IL, USA). A value of $p<.05$ was taken to indicate statistical significance.

## Results

The EMG activity of GMED and TFL, and GMED/TFL ratio with different types of isometric hip contraction during squat exercises are shown in Table 2.

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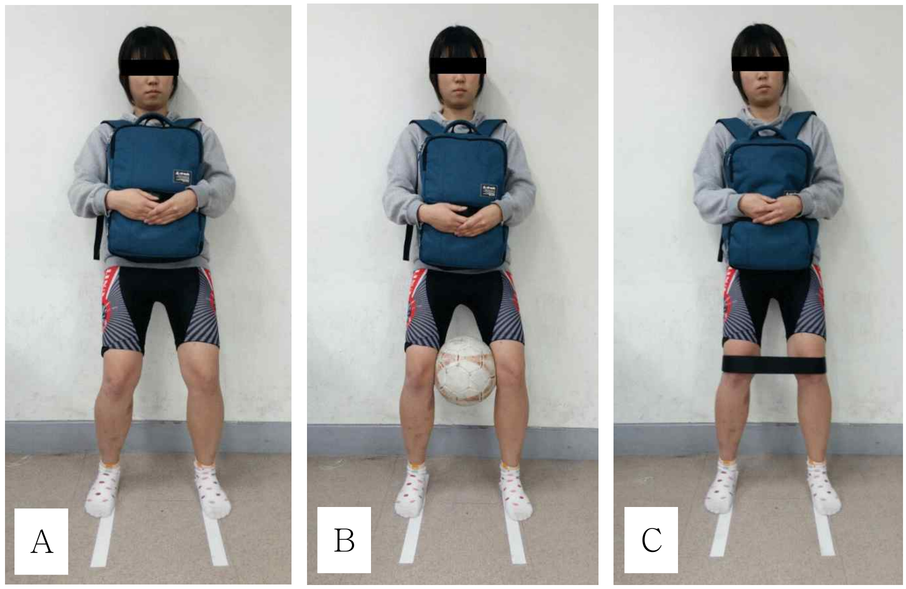


**Figure 1.** Squat exercises with three different types of isometric hip contraction conditions (A: standard squat without hip contraction, B: squat exercise with isometric hip adduction contraction, C: squat exercise with isometric hip abduction contraction).

### GMED EMG activity

The GMED EMG activity during isometric hip adduction and abduction contraction were significantly increased compared with the standard squat without hip contraction (p<.017). There were no significant differences in GMED EMG activity between the isometric hip adduction and abduction contraction conditions (p>.017) (Figure 2A).

### TFL EMG activity

The TFL EMG activity during isometric hip adduction and abduction contraction significantly increased compared with the standard squat without hip contraction (p<.017). Also, the TFL EMG activity significantly increased during squats with isometric hip adduction than isometric hip abduction (p<.017) (Figure 2B).

### GMED/TFL ratio

The GMED/TFL ratio significantly greater in isometric hip adduction vs. abduction contraction (p<.017). There were no significant differences in the GMED/TFL ratio between the standard squat without hip contraction and isometric hip adduction (p>.017) and abduction (p>.017) contraction conditions (Figure 3).

**Table 2.** Electromyographic activity of GMED and TFL, and GMED/TFL ratio during squat exercises with three different types of isometric hip contraction conditions (N=20)

| | Without hip contraction | Isometric hip adduction contraction | Isometric hip abduction contraction |
|---|---|---|---|
| GMED[a] (%MVIC[b]) | 5.13±4.01[c] | 28.71±19.75* | 25.91±17.08* |
| TFL[d] (%MVIC) | 3.25±1.95 | 17.46±16.86*† | 28.03±24.23* |
| GMED/TFL ratio | 2.02±1.58 | 2.40±1.33† | 1.27±.73 |

[a]gluteus medius, [b]maximal voluntary isometric contraction, [c]mean±standard deviation, [d]tensor fasciae latae,
*significant difference compared to 'without hip contraction' condition (p<.017), † significant difference compared to 'isometric hip abduction contraction' condition (p<.017).

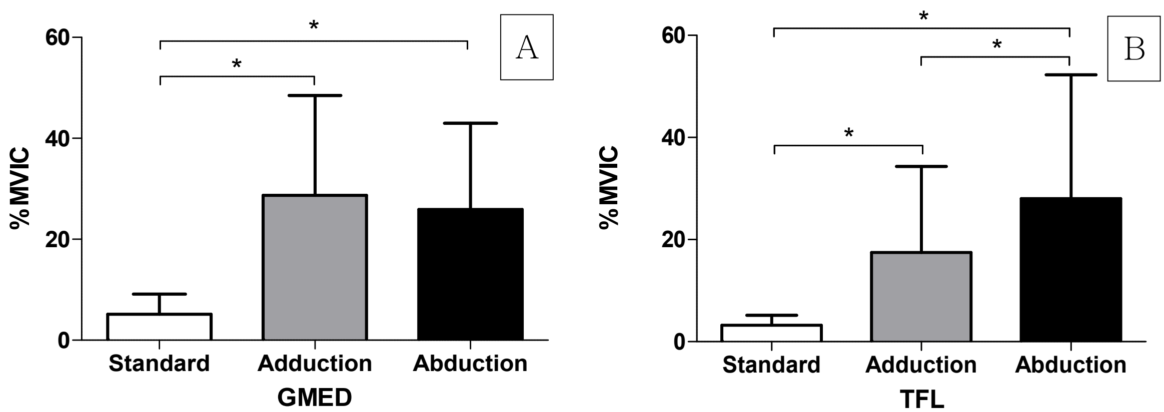


**Figure 2.** The muscle activity of GMED (A) and TFL (B) during squat exercises involving three different types of hip contraction conditions (GMED: gluteus medius, TFL: tensor fasciae latae, MVIC: maximal voluntary isometric contraction, error bar: standard deviation, *$p<.017$).

## Discussion

This study investigated GMED and TFL muscle activity, and the GMED/TFL ratio, during squat exercises under three different hip contraction conditions. Our results support the hypotheses that GMED and TFL EMG activity is significantly increased during isometric hip adduction and abduction contraction, and that the GMED/TFL ratio during isometric hip adduction contraction is significantly greater than it is during abduction contraction.

GMED EMG activity was significantly greater in the isometric hip adduction and abduction contraction conditions compared with the standard squat without hip contraction. In addition, GMED EMG activity showed similar muscle activation in the isometric hip adduction and abduction contraction conditions. Our findings are consistent with previous research indicating that squat exercises performed in a closed vs. open kinetic chain, with isometric hip adduction and abduction contractions, generate greater GMED muscle activity in healthy subjects (Distefano et al, 2009). Previous research has also demonstrated that, for all gluteal muscles tested, internal hip rotation moment arms increase, and external rotation moment arms decrease, during hip flexion (Delp et al, 1999; Distefano et al, 2009; Nyland et al, 2004). Therefore, the posterior section of the GMED can provide an external hip rotation moment during hip flexion. Greater GMED contraction during isometric hip adduction and abduction contraction could act to dynamically stabilize the hips and control excessive hip adduction and internal rotation of the femur, thereby preventing patellofemoral joint and ITB stress (Felício et al, 2011; Gottschalk et al, 1989). However the threshold of 40~60%MVIC is recommended to facilitate GMED strength gains (Andersen et al, 2006), GMED muscle activity of isometric hip adduction (28.71±19.75%) and abduction (25.91±17.08%) condition may be insufficient to produce GMED strength gains in healthy subjects. So it is necessary

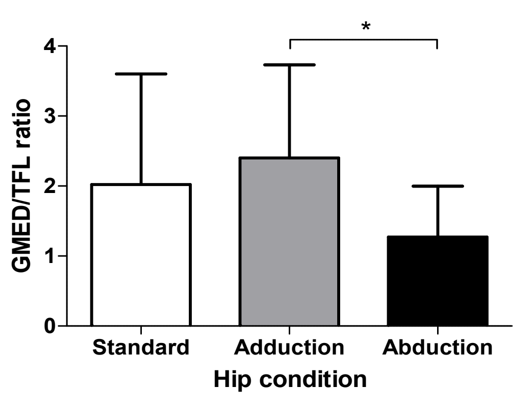


**Figure 3.** The GMED/TFL ratio during squat exercises involving three different types of hip contraction conditions (GMED: gluteus medius, TFL: tensor fasciae latae, error bar: standard deviation, *$p<.017$).

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to make up for the weak points in the GMED muscle strength gains.

TFL EMG activity was greater during isometric hip adduction and abduction contraction compared with standard squats without hip contraction, and the isometric hip adduction contraction was significantly greater than the isometric hip abduction contraction. In a study by Gottschalk et al (1989), Ober's test of abduction contracture, used during physical examinations to identify tightness of the ITB or ITB friction syndrome, demonstrated that TFL represents the major hip abductor. Furthermore, TFL exerts a force essential for maintaining balance during the full stance phase of the gait cycle (Gottschalk et al, 1989). Evans (1979) reported that the ITB assists the GMED in preventing Trendelenburg gait (an abnormal gait due to GMED weakness) and cites a case of ITB release during trochanteric bursitis (i.e., a weak or paralyzed GMED). Therefore, the TFL functions to control the balance of the lower extremity (Gottschalk et al, 1989). Our data suggest that the TFL may acts not only as a hip abductor synergist but also as a dynamic hip stabilizer in conjunction with hip abductor muscles such as the GMED.

The GMED/TFL ratio was significantly increased during isometric hip adduction vs. abduction contraction squats. The greater GMED/TFL ratio suggests higher GMED muscle activity than TFL muscle activity. Our data indicate that the greater GMED activation during squat exercises with hip isometric adduction could be clinically useful for the treatment of patellofemoral pain and ITB friction syndrome. However, the squat exercise with hip isometric abduction was also associated with greater TFL vs. GMED activity, which would not confer benefits for ITB friction syndrome (Powers, 2010; Selkowitz et al, 2013; Souza and Powers, 2009). The TFL exerts a lateral force on the patella, which is connected to the ITB. Recent clinical studies have demonstrated important connections between the ITB and the patella and lateral patellar retinaculum (Merican and Amis, 2008; Merican and Amis, 2009; Vieira et al, 2007). Merican and Amis (2009) also reported that, commensurate with increased flexion of the knee, ITB tension exerts a greater effect on patellar tracking. In addition, increasing ITB tension also increases lateral tilt and translation of the patella with tibial external rotation during knee flexion. Therefore, ITB tightness can lead to patellofemoral maltracking and lateral knee pain (Fairclough et al, 2007; Wu and Shih, 2004). Therefore, according as the muscle activity ratio of the GMED to the TFL during squat exercises, the squat exercise with isometric hip adduction contraction is the best exercise for increasing the GMED/TFL ratio. This study has a clinical interest and implications to physical therapists for supporting the hip abductor strengthening exercises to treat the patellofemoral pain (Boling et al, 2006; Khayambashi et al, 2012), and ITB friction syndrome (Beers et al, 2008; Fredericson et al, 2000).

There were several limitations to the current study. First, the generalizability of our results is limited because all of the subjects were young and healthy. In future studies, GMED and TFL muscle activity during the three types of squat exercise employed herein should be evaluated in subjects with weak GMED or dominant TFL muscles. Second, EMG muscle activity data were evaluated during the isometric contraction phase of each type of squat; differences between EMG activity during dynamic concentric and eccentric phases should be investigated, and may provide information that could improve dynamic strength and associated functional activities such as traversing stairs, the transition from sitting to standing, and running and jumping. Third, the squat exercises were just performed in 60° knee flexion. Various of angle of knee flexion during the three types of squat exercises should be examined in future studies. Fourth, the crosstalk that typically characterizes surface EMG might have occurred between GMED and TFL muscle activity. Finally, we employed a cross-sectional rather than longitudinal design; future studies should investigate the longitudinal effects of the three types of squat exercise to confirm and extend the present findings.

## Conclusion

This study investigated the GMED/TFL ratio during squat exercises involving three different types of hip contraction to which type would best activate the GMED than TFL muscle activity. The GMED/TFL ratio was significantly higher during isometric hip adduction vs. abduction. These data indicate that the GMED/TFL ratio of squat exercise with isometric hip adduction should be used for prevention and management of patellofemoral pain syndrome and clinically to enhance GMED muscle activity.

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