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Original Article

# Comparison of lower limb muscle activation with ballet movements (releve and demi-plie) and general movements (heel rise and squat) in healthy adults

Min-Ju Kim, MS, PT[1)], Joong-Hwi Kim, PhD, PT[2)*]

[1)] *Department of Physical Therapy, Graduate School, Catholic University of Daegu, Republic of Korea*
[2)] *Department of Physical Therapy, College of Medical Science, Catholic University of Daegu: John Sye Hall 510, Hayangro 13-13, Hayang-eup, Gongsan-si, Gyeongbuk, Republic of Korea*

**Abstract.** [Purpose] The aim of this study was to demonstrate therapeutic grounds for rehabilitation exercise approach by comparing and analyzing muscular activities of Ballet movements: the releve movement (RM) and the demi-plie movement (DM). [Methods] Four types of movements such as RM vs. heel rise (HM) and DM vs. squat movement (SM) were randomized and applied in 30 healthy male and female individuals while measuring 10-s lower limb muscular activities (gluteus maximus [GMa], gluteus medius [GMe], rectus femoris [RF], adductor longus [AL], medial gastrocnemius [MG], and lateral gastrocnemius [LG]) by using surface electromyography (EMG). [Results] Significant differences were found in GMa, GMe, AL and MG activities for DM and in all of the six muscles for RM, in particular when the two groups were compared (RM vs HM and DM vs SM). [Conclusion] The RM and DM have a greater effect on lower limb muscular force activities compared to HM and SM and could be recommended as clinical therapeutic exercises for lower limb muscle enhancement.

**Key words:** Dance movement, Lower limb muscle activation, Heel rise

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## INTRODUCTION

With increasing age, muscular force reduces owing to degeneration of muscular tissue/joint or neural lesions[1)]. In terms of lower limb muscular force, the gluteus maximus [GMa], gluteus medius [GMe], rectus femoris [RF], and medial gastrocnemius [MG] play important roles in effective movements upon posture maintenance during standing and walking. In addition, lower limb muscles that are necessary for desirable walking provide stability to the knee and hip joints[2, 3)]. However, walking speed and balancing ability decrease as well as simultaneous difficulties in posture maintenance can occur if patients develop lower limb muscle weakness[4, 5)]. In order to solve these problems, the heel rise movement (HM) and squat movement (SM) using self-weight are applied as exercises to prevent amyotrophy and enhance muscular force of the lower limb in clinical practice[1, 6, 7)]. Among dance movements involving stable self-weight, the releve movement (RM) and the demi-plie movement (DM) in Ballet are basic postures to be maintained by abducting a lower limb and recruiting the GMa, quadriceps Q, hamstrings, and MG that can be used to sufficiently develop the surrounding muscles including the Achilles tendon, foot arch, knee, and thigh, as well as the MG in particular[8, 9)]. Consistently and accurately performing RM and DM can develop the lower limb strength, maintaining body weight with plantar flexion and thus improving body balance[9, 10)]. In addition, some studies have reported that a dance program in patients with Parkinson disease was effective to improve memory, muscular force, and balance in a large number of patients[11)]. However, most of these studies were limited to Ballet majors and patients with Parkinson disease, and there is no study on the scientific evidence for therapeutic exercise movement and muscular

*Corresponding author. Joong-Hwi Kim (E-mail: ibobath@hanmail.net)

activity in healthy adults. In this regard, this study was conducted to compare and analyze lower limb muscle activities with Ballet movements, the RM and DM vs. general movements (HM and SM) in healthy people in order to suggest new rehabilitation therapeutic exercises involving dance movements in patients requiring muscular force exercises.

## SUBJECTS AND METHODS

Among healthy undergraduate students of C University in Gyeongsan-si, 30 target subjects (8 male and 22 female) without physical defects and who did not perform any exercises for the last 6 months and did not have any orthopedic disorder in the lower limb were selected for this study. The study subjects were fully informed of experimental procedures, and the subjects provided consent indicating their voluntary participation; and the study was approved by the Ethics Committee. The subjects were 22.2±1.9 years old, were 166.7±7.6 cm tall and weighed 60.7±9.8 kg. Among the 30 subjects, 26 were right lower limb-dominant whereas 4 were left lower limb-dominant. In this study, 6 types of muscles, i.e., the GMa, GMe, RF, AL, MG, and LG were assessed in order to compare lower limb muscular activities for 4 different movements, i.e., RM vs. HM and DM vs.SM, in healthy adults.

The ready-postures of RM and DM before starting Ballet movements are as below: Both heels are in contact each other while holding the foot at 60° at an open-angle, and both knees face outward while holding external rotation with the knee and ankle joints from the hip joint[12]. The posture assessed is as below: For RM, the heels are raised as high as possible while holding knee extension at the ready-posture. For DM, the knee joint faces towards the second toe while holding 45° of knee flexion at the ready-posture.

For the ready-posture for general exercises of HM and SM, the natural standing position is taken with the feet at shoulder width and the feet parallel forward. (The ready-posture for general exercises (HM and SM) is taken with the feet at pelvic width and the feet parallel forward like the natural position.)

For HM, the heels should be raised as high as possible from the natural position. For SM, the knee flexion should be held at 45° form the natural position. All movements were assessed with both hands in contact with the bar while the second finger of both hands was closed. RM and HM were assigned as into one group because both required raising of the heels as high as possible against gravity while maintaining knee extension but with different lower limb array positions. Similarly, DM and SM were assigned into one group because both involved same gravity directional movements but with different lower limb array positions while maintaining 45° knee flexion[13].

The test was conducted 2 times by maintaining the posture for total 10 s with 30-s rest intervals[14]. The experimental order was determined randomly. Using surface EMG (LXM5380, LAXTHA, Korea), an EMG signal was given for 10 s. The values at the first and the end of 2 second were excluded, and the value at 6 s was reported for RMS (root mean square) and the mean value of two measurements was used. (EMG signal was measure for 10s. The values at the first and the end of 2 second were excluded. And then I chose the value of 6s. The value at 6 s was reported for RMS (root mean square) and the mean value of two measurements was used.)

At the signal process of the EMG, RMS was used to change the contracting muscle[15]. These data were statistically analyzed by using SPSS Ver 20.0. Differences between the two groups, RM vs. HM and DM vs. SM in 6 muscular activities were verified using a paired t-test with statistical significance at $p < 0.05$.

## RESULTS

The RM vs. HM group showed significant difference in all of 6 muscle activities, i.e., GMa, GMe, RF, AL, and MG ($p<0.01$**) and LG ($p<0.05$*) (Table 1). The RM vs DM group showed significant differences in GMa, GMe, MG ($p<0.01$**) and AL activities ($p<0.05$*), while no significant difference in RF and LG activities (Table 2).

## DISCUSSION

In this study, the effect of HM vs. RM and SM vs. DM on 6 muscular activities in healthy adults was examined by using EMG. The HM is widely recommended for patients with weak lower limbs to improve muscular force[1, 7], and the HM and RM are important for strengthening the lower limbs to improve medial and lateral MG that are important for ankle stability[7, 16, 17]. In addition, the HM and RM are the same and involve maintaining abduction and extension of the ankle, knee, and hip joints, while raising heels against gravity. However, in terms of the hip joint, the HM is performed from the natural posture whereas the RM is performed from the hip abduction posture; in this regard, the most effective movement in muscular activation among these was explored. Using EMG, muscular force change was observed with Ballet movements in dance majors, and muscular activation of GMa, RF, and MG was high and the muscular force of these muscles was higher than that of the upper limb muscular force[12, 18, 19]. The statistically significant values of GMa, GMe, RF, AL, MG and LG activation at RM and DM were similar to those observed in prior studies.

The SM is another lower limb exercise that greatly impacted the muscular forces such as the quadriceps and MG. As the SM and DM involve the same type of closed-kinetic-chain exercises simultaneously using ankle, knee and hip joint flexion but involve different start positions, i.e., the natural posture for SM and the abduction posture for DM, they were

**Table 1.** Comparison of muscle activation between releve movement (RM) and heel rise movement (HM) (mean±SD) (n=30)

| Muscles | Releve | Heel rise |
|---|---|---|
| Gluteus maximus | 16.1± 10.8 | 7.8± 2.3** |
| Gluteus medius | 29.3± 17.0 | 5.6± 2.0** |
| Rectus femoris | 36.9± 18.0 | 21.1± 15.6** |
| Adductor longus | 24.2± 13.5 | 9.9± 5.9** |
| gastrocnemius medialis | 160.1± 50.2 | 129.3± 50.8** |
| gastrocnemius lateralis | 63.6± 32.1 | 73.0± 40.2* |

*p<0.05, **p<0.01 (paired t-test)

**Table 2.** Comparison of muscle activation between demi-plie movement (DM) and squat movement (SM) (mean±SD) (n=30)

| Muscles | Demi-plie 45° | Squat 45° |
|---|---|---|
| Gluteus maximus | 19.6± 12.5 | 10.7± 4.6** |
| Gluteus medius | 27.2± 18.1 | 8.7± 4.8** |
| Rectus femoris | 53.0± 1.0 | 43.8± 16.0* |
| Adductor longus | 14.6± 9.2 | 13.6± 3.7 |
| Gastrocnemius medialis | 13.6± 6.9 | 9.9± 3.7** |
| Gastrocnemius lateralis | 14.3± 10.5 | 10.7± 3.8 |

*p<0.05, **p<0.01 (paired t-test)

performed to determine differences in muscular activation. The result showed that the muscular activation of GMa, GMe, AL, MG was higher in DM than in SM. This may be because of the lower limb abduction posture and the straight hip and waist line-maintaining movement[18, 20]. The study conducted by Dong-Cheon[21] showed that the hip joint enhancing exercise (This study is muscular activation of hip joint movement (hip adduction and hip abduction).) resulted in higher activation of GMa and GMe at hip joint adduction posture rather than at abduction posture. The higher muscular activation at DM than at SM appeared, because the investigator instructed the subjects to hold the hip and waist line straight by maintaining a slight posterior pelvic tilting movement, and the hip joint extensor and the abdomen muscles were activated owing to posterior pelvic tilting maintenance[22]. Bennell et al.[23] reported improvement in lateral and internal rotator muscles that are important to the hip and lower limb stability after Ballet movement exercise at abduction. Therefore, the RM and DM are considered to have higher effect lower limb activation due to posterior pelvic tilting movement at hip joint abduction posture whereas the HM and SM are considered to have a lower effect than the RM and DM due to hip joint movement performed at the natural position.

This study results provide experimental evidence of significantly increased muscular activation with Ballet movements on the basis of a comparison between RM and DM compared to the general lower limb movements (HM and SM) through statistical verification. These suggest that the RM and DM could be used for rehabilitation for patients requiring improvement in the force of GMa, GMe, RF, AL, MG, and LG in the future.

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