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Original Article

Effects of walking with a “draw-in maneuver” on the knee adduction moment and hip muscle activity

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Abstract. [Purpose] To investigate the effect of performing a draw-in maneuver (DI) on knee adduction moment (KAM) and hip and trunk muscle activities while walking. [Participants and Methods] We included 30 healthy young adults (21.5 ± 0.6 years, 16 males and 14 females) in this study. We measured the KAM and lever arm while participants walked with either a normal gait or a DI gait. We also performed surface electromyography (EMG) of the hip and trunk muscles (i.e., internal oblique abdominal muscle [IO], external oblique abdominal muscle [EO], multifidus muscle [MF], and gluteus medius muscle [GM]). [Results] The 1st peak of the KAM was significantly lower when walking with a DI gait compared to when walking with a normal gait. The integrated EMG activity of the IO, EO, and GM during the 1st half of the stance phase, and of the IO and EO during the 2nd half of the stance phase was significantly higher during the DI than during normal gait. [Conclusion] Compared with a normal gait, a DI gait leads to a decrease in the 1st peak of the KAM as a result of the shorter lever arm, and an increase in the muscular activity of the GM, IO, and EO.

Key words: Draw-in maneuver, Knee adduction moment, Hip abduction muscle activity

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INTRODUCTION

Knee osteoarthritis (OA) is a widespread degenerative joint disease that causes poor physical function in middle-aged and older persons[1–3)]. A high knee adduction moment (KAM) while walking is related to advancing medial knee OA[4, 5)]. Gait modifications that reduce the KAM may therefore contribute to prevent knee OA[6–8)]. A toe-out gait[9, 10)], toe-in gait[11, 12)], and a gait with an increased trunk lean[13, 14)] effectively reduce the KAM. Patients with knee OA often tend to adopt a toe-out gait or trunk lean gait as a compensatory gait pattern[15, 16)]. Shull et al.[8)] studied the effects of a 6-week gait modification period to reduce the KAM and knee pain, and demonstrated that the trunk lean gait modification is associated with discomfort, difficulty maintaining posture, and decreased balance. Adherence to gait modifications with voluntary and forced trunk and leg alignment changes, however, may be difficult over the long-term.

A gait modification that requires no voluntary alignment change is the draw-in maneuver (DI), which is reported to improve thoracic kyphosis and reduce the KAM[17)]. In the DI maneuver, participants are asked to bring their belly button up and toward the spine as they exhale, thereby contracting the abdominal muscles and increasing stability[18)]. Ota et al.[17)] reported that the KAM in a healthy population was significantly reduced by walking with a DI maneuver (DI gait) in which the thoracic kyphosis angle is decreased as measured in a standing position while performing the DI maneuver. The authors considered that insufficient instruction for the DI gait, i.e., a simple verbal command to “decrease the abdominal circumference”, was a limitation of previous studies[17)]. Therefore, proper instruction regarding the DI maneuver and confirmation of the activities of the abdominal and paravertebral muscles are necessary for studying the effects of the DI gait[19)].

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Several studies have examined the effect of the DI gait on core stability, focusing on physical function[20, 21)] and low back pain[22)], but few studies have examined the hip muscle activities during the DI gait. Weak hip muscles, especially the gluteus medius muscle (GM), are associated with an increased KAM[23)]. The pelvic drop on the swing side due to weak hip abduction muscle leads to a longer frontal plane KAM lever arm[23)]. Hinman et al.[24)] reported that the GMs are weak in patients with knee OA. A gait modification that decreases the KAM and increases GM activity is expected to be useful toward preventing knee OA[25)].

In the present study, we investigated the effect of performing the DI gait with appropriate instruction for reducing the KAM and increasing hip and trunk muscle activities.

PARTICIPANTS AND METHODS

Thirty healthy young adults (16 males, 14 females) were enrolled in the present study. Participants were recruited by distributing leaflets and posters placed on a bulletin board available to the student body of the Seijoh University Department of Rehabilitation and Care according to the following inclusion criteria: 1) absence of current musculoskeletal pain or muscle disorders and 2) no previous musculoskeletal surgery. Each of the participants provided informed written consent. The Ethics Committee of Seijoh University approved the study (approval number: 15PT06). Mean age, height, weight, and body mass index (BMI) of the participants were 21.5 ± 0.6 years, 165.2 ± 10.0 cm, 56.2 ± 9.7 kg, and 20.5 ± 2.3 kg/m^2, respectively.

A 10-camera motion analysis system (Venus 3D; Nobby Tech, Tokyo, Japan) was used to collect the 3-dimensional (3D) trajectory data, which were sampled at 100 Hz and digitally recorded. A force plate (AccuGait; AMTI, Watertown, MA, USA) synchronized to the 3D motion analysis system was used to collect the ground reaction forces with a 100-Hz sampling rate. For each participant, reflective sphere markers (7 mm in diameter) were attached to 25 anatomic locations as well as to thigh and lower leg plates.

Tasks were performed with the participants walking barefoot at a controlled speed within ± 5% of the standard speed set for Japanese[26)] as measured at the 2nd sacrum marker. Participants were asked to walk a 6-m walkway 3 times and the trials were recorded.

A 4-link gait model, including segments for the pelvis, thigh, lower leg, and foot was used. The positions of the segments were estimated according to a global coordinate model[27)], and the data from all markers obtained during static calibration were used to customize the model for each participant. The segment-embedded reference frames for the associated body segments were defined on the basis of the marker coordinates obtained above[28)]. The inertial properties for each limb segment were based on Japanese inertial characteristics[29)]. The center of the knee joint was defined as the midpoint between the lateral and medial femoral epicondyle.

Inverse dynamics were applied for calculating the external KAMs, which were normalized to body mass and leg length according to the height of the trochanter marker during the static calibration[30)]. The mean of the 3 trials was used to analyze the KAMs. All data were normalized to 100% of a gait cycle with 0% heel contact of the measured leg. We measured the 1st and 2nd KAM peaks during the stance phase (0–30% and 30–60% of the gait cycle)[31)]. The length of the KAM lever arm was defined as the perpendicular distance between the ground reaction force vector and the center of the knee joint in the frontal plane. Lever arms were determined at the 1st and 2nd KAM peaks.

Measurements were obtained while the participants walked first with a normal gait and then with the DI gait. For the DI gait, participants received verbal instructions to "Please draw your belly button up and in towards your spine as you exhale. Please hold this condition without forward inclination of the trunk", with confirmation of the posture during standing and walking[32)]. A general 5-mm wide polypropylene rope was placed around the body at the level of the navel to help participants maintain the contracted abdominal circumference during the DI gait. The rope was 2.1 cm shorter than the abdominal circumference and both ends of the rope were taped together; the tape came off when the abdomen expanded, as described in a previous study[17)].

Surface EMG of the trunk and hip muscles on the measured leg side was obtained to evaluate the activities of the internal oblique abdominal muscle (IO), external oblique abdominal muscle (EO), multifidus muscle (MF), and GM. The IO, EO, and MF are contracted while performing the DI maneuver[19)], which is thought to lead to increased trunk stability[33)], and contracting the GM is considered to reduce the KAM[34, 35)]. Surface EMG of the IO, EO, MF, and GM was obtained using disposable silver/silver chloride surface electrodes having a recording diameter of 1 cm (Blue Sensor M-00-S, Ambu Corp, Copenhagen, Denmark). Bipolar electrode pairs and a ground electrode were positioned longitudinally over the IO, EO, MF, and GM at 2.5 cm intervals according to standard instructions (i.e., SENIAM recommendations [Biomedical Health and Research Program of the European Union] and Cram's instructions [Criswell E. Cram's Introduction to Surface Electromyography]). The EMG signals from each muscle were recorded using an EMG acquisition system (Mwatch; Wada Aircraft Technology Co., Ltd., Kiyosu, Japan). EMG signals were sampled at 1,000 Hz, amplified, and band-pass filtered (10 ± 300 Hz), and then rectified. Integrated EMG (iEMG: mVs) of the 4 muscles in the 1st and 2nd halves of the stance phase were used in the final analysis.

The Shapiro-Wilk test was used to assess the normality of the data distribution. When the data were normally distributed, a paired t-test was used to analyze differences in the biomechanical values between the normal and DI gait conditions. When the data were non-normally distributed, we applied the Wilcoxon signed-rank test. A $p<0.05$ was considered significant. The effect size (Choen's d) was evaluated for all comparisons. All statistical analyses were performed using SPSS, Version 16.0 (IBM Japan, Chuo Ward, Tokyo, Japan).

RESULTS

The 1st and 2nd KAM peaks are provided in Table 1. The 1st KAM peak was significantly lower during the DI gait compared with that during the normal gait ($p<0.05$). The lever arm lengths at both KAM peaks are also presented in Table 1. The lever arm length at the 1st KAM peak was significantly shorter during the DI gait than that during the normal gait ($p<0.05$).

The iEMGs of the IO, EO, and GM during the 1st half of the stance phase and the iEMGs of the IO and EO during the 2nd half of the stance phase were significantly increased when the participants walked with the DI gait compared to the normal gait (Table 2).

DISCUSSION

The findings of the present study demonstrated that providing adequate instructions for a DI maneuver that achieves a 2 cm decrease in abdominal circumference while walking significantly decreased the 1st KAM peak. A previous study reported that the KAM was significantly reduced by walking with the DI gait in which the thoracic kyphosis angle was decreased as measured in a standing position while performing the DI maneuver as compared with that during a normal gait[17)]. In the present study, KAM was decreased simply by instructing the participant to shrink the abdominal circumference and confirming the posture without measuring the thoracic kyphosis angle. Suehiro et al.[36)] reported that tape measure-based feedback provided when patients performed a DI maneuver effectively facilitated the isolation of transverse abdominal contractions in the crook lying, sitting, and standing positions compared with no feedback. Here we placed a general polypropylene rope around the body at the level of the navel to help maintain the contracted circumference during the DI gait. Both IO and EO activities were increased when participants walked with the DI gait compared with a normal gait, indicating that proper instruction facilitated performance of the DI maneuver, which was useful for decreasing the KAM.

We evaluated the effect of a gait modification to reduce the KAM. Compared with a normal gait, the DI gait significantly decreased the 1st KAM peak with a mean percent decrease of 5%. Several studies have evaluated the effects of various gait modifications to reduce the KAM, such as walking 15% slower than a self-selected walking speed, which decreases the 1st KAM peak by 8%[37)]. Adding a 6° trunk lean while walking also reduces the 1st KAM by 9%, compared with a normal gait[13)].

Table 1. Comparison of biomechanical data between normal gait and gait with draw-in maneuver

	Normal gait	DI gait	p-value	ES
1st KAM ($\times10^{-2}$: no unit)	5.5 ± 1.2	5.2 ± 1.4	0.003	0.28
2nd KAM ($\times10^{-2}$: no unit)	5.4 ± 1.7	5.4 ± 1.5	0.839	0.01
1st LA at peak 1st KAM (mm)	38.3 ± 12.3	35.7 ± 11.5	0.006	0.21
2nd LA at peak 2nd KAM (mm)	39.0 ± 10.9	39.2 ± 10.4	0.959	0.02

DI: draw-in maneuver; ES: effect size; KAM: knee adduction moment; LA: lever arm.

Table 2. Comparison of the iEMG of the trunk and hip muscles during the 1st and 2nd halves of the stance phase

(Unit: mVs)	Normal gait	DI gait	p-value	ES
1st half of stance phase				
IO	2.77 ± 1.62	3.80 ± 2.34	0.001	0.64
EO	3.10 ± 1.34	3.94 ± 1.55	<0.001	0.63
MF	4.22 ± 1.82	4.46 ± 1.97	0.251	0.14
GM	2.73 ± 1.29	3.03 ± 1.57	0.037	0.23
2nd half of stance phase				
IO	2.49 ± 1.40	3.58 ± 2.15	<0.001	0.78
EO	2.43 ± 0.99	3.27 ± 1.43	<0.001	0.85
MF	3.22 ± 1.45	3.57 ± 1.48	0.054	0.24
GM	1.87 ± 0.91	2.14 ± 1.34	0.098	0.30

DI: draw-in maneuver; ES: effect size; IO: internal oblique abdominal muscle; EO: external oblique abdominal muscle; MF: multifidus muscle; GM: gluteus medius muscle.

A toe-out gait has variable effects on the early-stance KAM, with changes ranging from a decrease of 55.2% to an increase of 12.9%[38)]. Further, a Nanba walking style decreases the 1st KAM by 11%[39)]. Together, these findings indicate that gait modifications may have various advantageous effects for reducing the 1st KAM peak. The DI gait is suggested to decrease the KAM without changing the voluntary leg alignment or trunk inclination, but this has not been verified. Further investigation is needed to confirm whether a 5% decrease in the KAM is enough to be beneficial over the long-term.

The decrease in the KAM is assumed to be due mainly to the significantly shorter lever arm length at the 1st KAM peak when walking with a DI gait than when walking with a normal gait (Table 1). The GM activity is significantly higher when walking with a DI gait compared with a normal gait. The increased GM activity ameliorates the pelvic drop on the opposite side. High activity of the hip and trunk muscles during the DI maneuver could facilitate a smooth lateral shift of the center of mass toward the stance foot, further shortening the lever arm in the stance phase. Therefore, the high GM activity could help to decrease the KAM. That is, during the DI gait, the GM activity is high, which is assumed to decrease the pelvic drop on the swing leg side as well as to decrease the lever arm length due to a shift of the center of the body mass toward the stance limb, thereby preventing increases in the KAM. Additionally, the KAM magnitude is significantly increased by a pelvic drop alone, which is a risk factor for the progression of knee OA[14)]. Hinman et al.[24)] demonstrated that, compared with asymptomatic controls, people with knee OA have significant hip abduction muscle weakness. As described above, the DI gait might prevent knee OA by increasing the activity of the hip abduction muscle in addition to decreasing the KAM.

In the present study, the participants were healthy individuals and only the immediate effect of the gait modification was examined, which may be considered limitations. Further studies should be performed to verify the long-term effects of the DI gait in patients with knee OA and other diseases associated with knee OA, such as diabetes mellitus and obesity[37)], including the compliance rate of applying the DI gait.

Compared with a normal gait, walking with the DI gait led to a decrease in the 1st KAM peak by shortening the lever arm and increasing the activities of GM, IO, and EO muscles under the same controlled walking speed.

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Conflict of interest

The authors declare no conflicts of interest.

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