Clinical Case Report

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The effect of anti-gravity treadmill training for knee osteoarthritis rehabilitation on joint pain, gait, and EMG

Case report

Junjie Liang, MMed, Shijuan Lang, MBBS, Yuxin Zheng, BS, Yujue Wang, MD, Hongxin Chen, BS, Jinyu Yang, BS, Zhiwei Luo, BS, Qiang Lin, PhD, MD*, Haining Ou, PhD, MD*

Abstract

Introduction: To date, the anti-gravity treadmill (AlterG), as a representative method of Lower body positive pressure (LBPP) treadmills, has been rarely reported for knee osteoarthritis (KOA) rehabilitation. The purpose of this case study was to setup the clinical protocol example for AlterG intervention on KOA and evaluate treatment effectiveness by 3D gait analysis combined with free EMG to explore the kinematic gait parameter changes.

Patient concerns: A 65-year-old female patient (BMI = 26, mild obesity) undergoing "more than 7 years of KOA." The activity of the right knee joint was obviously limited and she suffered from severe pain over the past month.

Diagnosis: Due to the patient's symptoms and radiographic findings, she was diagnosed with acute attack of KOA.

Interventions: The patient has performed clinical function evaluation and gait analysis combined at pretreatment, post-treatment, and 4 months follow-up assessment. AlterG training was performed 6 days/week for 2 weeks, with up to 30 min of training per session. The training protocol included two major parts, walking and squatting in AlterG.

Outcomes: After 2 weeks of AlterG intervention, the 10-m walking test (10 MWT) and Timed-up-and-go (TUG) test improved significantly post-treatment, whereas the Visual Analog Scale (VAS) score decreased post-treatment. The Modified Barthel Index improved post-treatment and the patient restored basic community walk after treatment. The temporal parameter results showed that stride length (%height), mean velocity (%height), and cadence gradually increased before treatment, after treatment, and at 4-month follow-up. The right range of motion (ROM) of knee flexion-extension were gradually increased. Meanwhile, the synchronized EMG data showed that the RMS (root means square) values of the rectus femoris, semitendinosus, and biceps femoris at post-treatment were improved to different degrees than at pretreatment.

Conclusion: We found that for this patient with KOA, AlterG relieved pain, and was also effective at improving spatio-temporal parameters, knee flexion/extension gait pattern, and corresponding muscle strength, thereby restoring certain community activities.

Abbreviations: 10 MWT = 10-m walking test, AlterG = anti-gravity treadmill, BMI = body mass index, BWSTT = body weight-supported training, EMG = electromyography, KOA = knee osteoarthritis, LBPP = lower body positive pressure, RMS = Root-Mean-Square, TUG = Timed-up-and-go test, VAS = Visual Analog Scale.

Keywords: AlterG, anti-gravity treadmill, EMG, gait analysis, knee osteoarthritis, lower body positive pressure supported treadmill, rehabilitation

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The authors declare that there is no competing interest regarding the publication of this article.

Department of Rehabilitation, The Fifth Affiliated Hospital of Guangzhou Medical University, Guangzhou, China.

** Correspondence: Haining Ou, Qiang Lin, Department of Rehabilitation, The Fifth Affiliated Hospital of Guangzhou Medical University, Guangzhou 510700, China (e-mails: 827367058@qq.com, qianglin0925@gzhmu.edu.cn).*

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1. Introduction

Knee Osteoarthritis (KOA) is a disease characterized by degenerative changes and destruction of articular cartilage.[1] Continued disease progression leads to gradual impairment of knee function and causes corresponding pain and decreased muscle strength, which associated with maintaining knee stability,[2] resulting in decreased exercise and increased body mass index (BMI),[3] further aggravating knee joint burden and damage.[2–4] Due to the above changes, daily life activities are affected accordingly.[5,6] The management of KOA based on the Evidence-Based Guidelines involves exercises and strength training and weight control.[7] Therefore, appropriate exercise therapy, such as aerobic exercise, has been known as an effective countermeasure.[8] However, clinical application of such therapy is difficult in patients with advanced KOA because of loading exacerbates joint pain, preventing intervention.[9] To overcome these issues, the anti-gravity treadmill (AlterG), as a representative method of Lower body positive pressure (LBPP) treadmills, has been recently proposed as a therapy for patients with osteoarticular diseases and could provide an alternative method for body weight-supported training (BWSTT) by providing a positive pressure chamber that surrounds the individual's lower body and the treadmill.[10]

The AlterG provides body weight support of up to 80% in 1% increments, allowing for a systematically graded exercise program modified to the specific needs of the client [11] (Fig. 1A). Compared with the suspension weight-reduction system (with a harness to lift the patient on a treadmill and the central part forms a concentrated pressure point), AlterG's advantages are mainly reflected in the patient's comfort during the weight loss process (with the air pressure increased by inflation and the resulting support).[12] The force is evenly distributed in the lower part of the human body, and the subject has no sense of pressure. Moreover, LBPP can promote venous return during walking, which significantly reduces heart rate.[13] All of the above advantages are beneficial to aerobic exercise in patients with osteoarthritis, especially in patients with cardiovascular disease and hypertension,[9] thus promoting the recovery of patients. However, as an emerging weight loss system, to date, there have been rarely reported investigations of the efficacy of AlterG for KOA rehabilitation. Previous studies have provided only indirect evidence that AlterG might be effective in the treatment of osteoarthritis. For example, Patil et al reported that AlterG could effectively reduce knee joint torque,[14] which (theoretically) is crucial for KOA patients. Kawae et al compared the exercise training of patients with lower extremity arthritis under the walking and weight-loss walking with suspension weight-reduction system, and the results showed that the anti-gravity group had significant advantages in pain, speed, and walking distance than the flat walking group.[15] AlterG is effective for patients with musculoskeletal injuries, such as prosthetic rehabilitation following below-knee amputation,[16] total knee arthroplasty[17] or anterior cruciate ligament reconstruction.[18] The purpose of this case study was, therefore, to setup the clinical protocol example for AlterG intervention on KOA and evaluate treatment effectiveness by 3D gait analysis combined with free EMG to explore the kinematic gait parameter changes.

2. Case description and methods

Our patient was a 65-year-old female patient (BMI=26, mild obesity) undergoing "more than 7 years of KOA." The activity of the right knee joint was obviously limited and suffered from severe pain over the past month. She could only walk with a stick, had difficulty to sit, stand and walk at home, and reduced activity, which seriously affected her daily life. On April 8, 2018, a right knee MRI was performed to exclude acute lesions but showed severe KOA with "knee joint effusion, knee joint clearance and articular surface hyperplasia" (Fig. 2). The patient signed a statement of consent to use photographs and laboratory data. Our study obtained a signed statement of consent from the Fifth Affiliated Hospital of the Guangzhou Medical University Ethics Committee.

3. Assessment

The patient has performed clinical function evaluation and gait analysis at pretreatment, post-treatment, and 4 months follow-up assessment. The mobility was assessed by 10-m walking test (10 MWT) and the Timed-up-and-go test (TUG test). Pain was assessed by Visual Analog Scale (VAS) pain score. Activities of daily living were assessed by modified Barthel index. Gait analysis was performed using BTS Smart DX 7000 (Bioengineering Technology System, Milan, Italy). Twenty-two spherical markers were positioned bilaterally on the patient's anatomical landmarks based on the Davis protocol[19] (Fig. 3). After calibration in the standing position, the patient was instructed to walk with a self-selected speed along the walkway. Temporo-spatial parameters and knee flexion/extension trajectory in the gait cycle were recorded and subjected to statistical analysis. Moreover, the muscular activity around the knee was collected by the BTS FREEEMG surface electromyogram simultaneously, including rectus femoris, semitendinosus, and long head biceps femoris.

4. Intervention

AlterG training was performed 6 days/week for 2 weeks, with up to 30 min of training per session. The training protocol included two major parts:

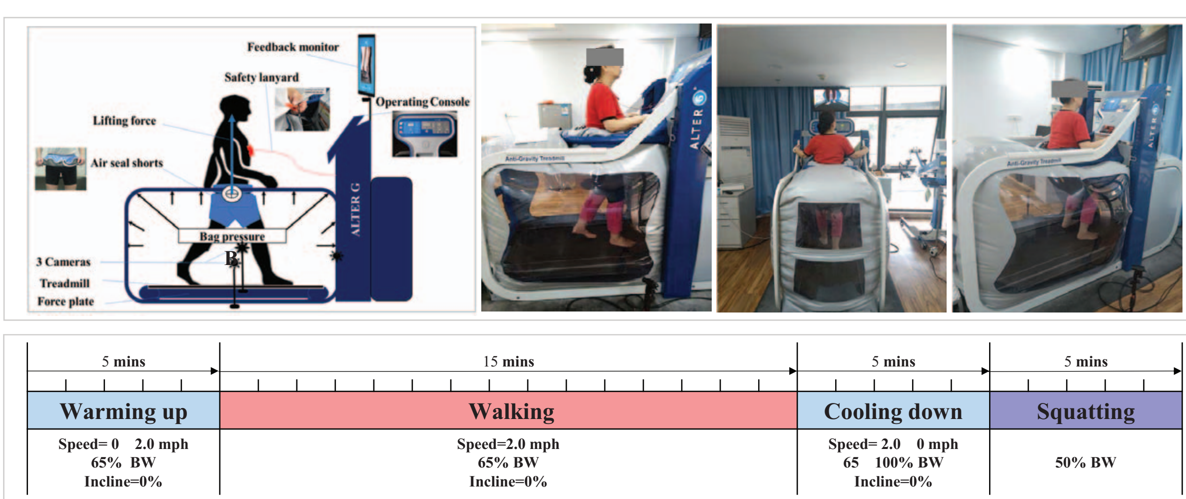
A
B


Figure 1. Diagram of AlterG setting up (A) and AlterG intervention protocol (B). (A) The AlterG setting up and the patient training on the anti-gravity treadmill. (B) The AlterG protocol consisting of warm-up phase (5 min), walking phase (15 min), cooling down phase (5 min), and squatting phase (5 min). BW=body weight, min= minute, mph=miles per hour.

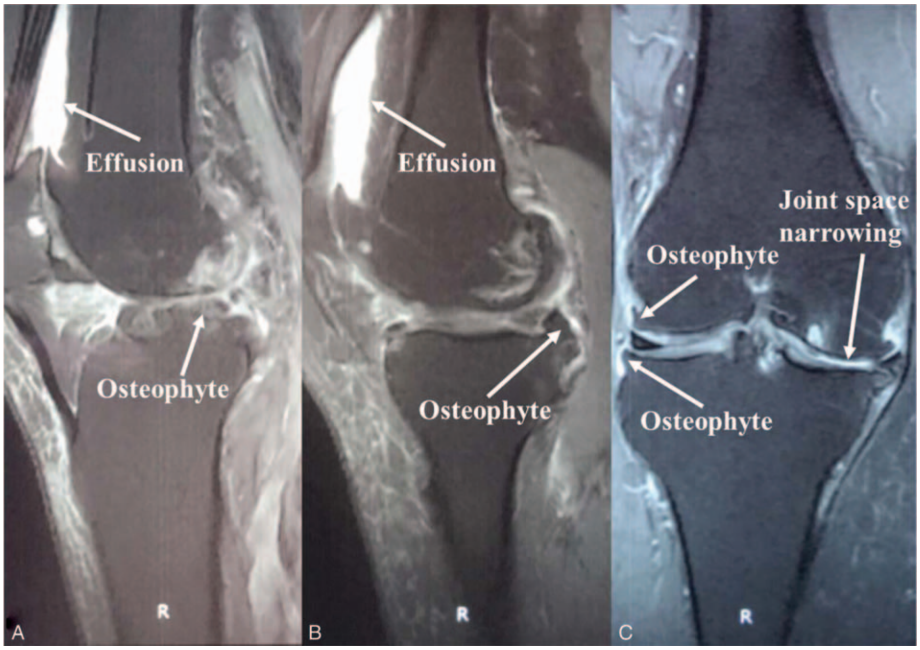


Figure 2. The MR image of the right knee. The sagittal view (A and B) and the coronal view (C) of right knee show roughened and thinning cartilage, osteophyte, and effusion (white arrows). MR = magnetic resonance, R = right.

1. Walking in AlterG: warming up for 5 min (speed = 0–2.0 mph, BW = 65%, incline = 0%); walking for 15 min (speed = 2.0 mph, BW = 65%, incline = 0%); cooling down for 5 min (speed = 2.0–0 mph, BW = 65–100%, incline = 0%, for 5 min);

2. Squatting in AlterG: squatting for 5 min (speed = 0 mph, BW = 50%, incline = 0%, 30 s squatting followed with 30 s rest, mph means miles per hour, and BW means body weight). The patient also got the synchronized video feedback during the training process to help patient correcting abnormal movement patterns (Fig. 1B).

5. Results

The results of the clinical function assessments are shown in Table 1. The VAS pain scale was decreased from 5 points at pretraining to 3 points at post-training, and 2 points at 4-month follow-up. The 10 MWT was decreased from 12.0 s at pretraining to 8.6 s at post-training. The patient maintained his improvement at 4-month follow-up with 7.3 s; The TUG test was decreased from 21.2 s at pretraining to 12.7 s at post-training. The patient maintained this improvement at 4-month follow-up with 12.1 s.

The results of gait parameters and EMG activities are shown in Figs. 4 and 5. The right stride length (%height) was increased from 53.7 at pretraining to 58.59 at post-training and 70.41 at 4-month follow-up; The mean velocity (%height) was increased from 39.33 at pretraining to 47.24 at post-training and 62.73 at 4-month follow-up; the step length was increased from 0.20 m at pretraining to 0.09 m at post-training, and 0.10 m at 4-month follow-up; the cadence (steps/min) was increased from 87.9 at pretraining to 95.25 at post-training, and 106 at 4-month follow-up; the RMS amplitude of right rectus femoris, right semitendinosus, and right long head biceps femoris were increased from 0.192 ± 0.012, 0.155 ± 0.011,and 0.194 ± 0.048 mV at pretraining to 0.204 ± 0.014, 0.209 ± 0.006, and 0.229 ± 0.017 mV at post-training, and 0.244 ± 0.010, 0.254 ± 0.010, and 0.357 ± 0.037 mV at 4-month follow-up, respectively.

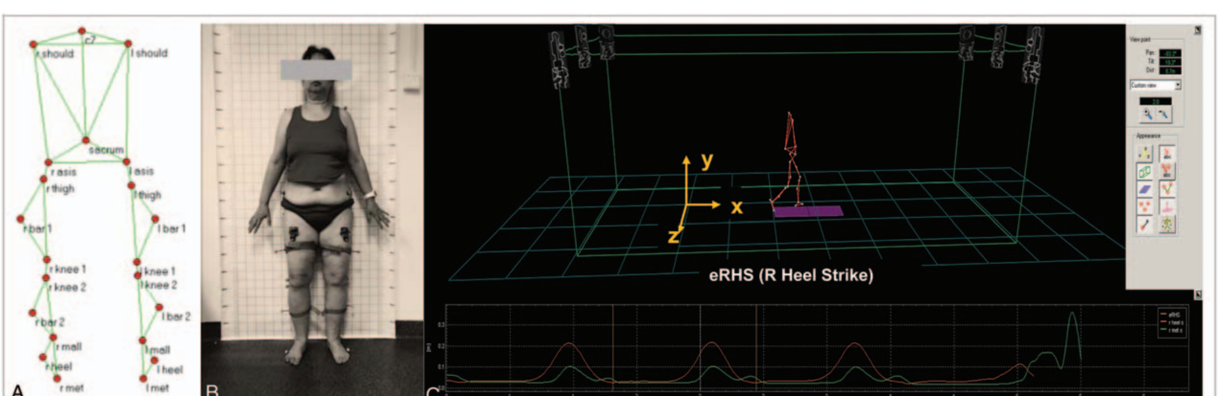


Figure 3. BTS gait analysis system setting up. (A) and (B) show marker positioning based on Davis protocol. (C) The BTS software interface of data acquisition. asis = anterior superior iliac spines, c7 = cervical 7, eRHS = R heel strike, which means right foot initial ground contact (at least two events must be defined), mall = malleolus, met = metatarsus, l = left, r = right.

Table 1

Patient demographics and clinical assessment data at pre-treatment, post-treatment and follow up.

	Baseline characteristic	Pre-treatment	Post-treatment	4M follow up
Gender	Female			
Age (years)	65			
Weight (kg)	63			
Height (cm)	158			
VAS (1–10)		5	3	2
10MWT (s)		12.0	8.6	7.3
TUG (s)		21.2	12.7	12.1
Modified Barthel index (0–100)		85	100	100

4M = 4 months, 10 MWT = 10-m walking test, cm = centimeter, kg = kilogram, s = second, TUGT = time up and go time, VAS = Visual Analog Scale.

6. Discussion

Synovitis is a common pathological type of osteoarthritis, which causes joint cavity adhesions, increased release of inflammatory factors, and blocked joint fluid reflux, causing knee pain.[20] Previous studies have shown that exercise therapy can reduce joint symptoms of OA, such as pain, stiffness, and fatigue, while improve joint function, walking speed and strength.[21–23] AlterG anti-gravity treadmill uses the LBPP principle to provide accurate weight reduction, which can realize the lower limb exercise training for the KOA patient with severe pain and limited ROM of the knee as soon as possible, thereby promoting the secretion, metabolism, and circulation of synovial fluid in the joint cavity, reducing the increase of inflammation and wear in the joint cavity, and achieving the treatment of KOA.

The patient's primary rehabilitation appeal was to improve pain and joint stiffness and to resume walking in community independently as soon as possible. Therefore, the patient's AlterG training protocol included weight loss walking training in AlterG (dynamic exercise part) to improve walking ability, and an innovative brought up weight loss squat training (static exercise part) to reduce joint mobility limitations.

After 2 weeks of AlterG intervention, the clinical assessment scales showed that the knee joint clinical symptoms and lower limb walking ability had different degrees of improvement. The 10 MWT and TUG test points improved significantly at post-treatment, suggesting that the patient's lower limb walking endurance and sit-to-up transfer ability improved compared to pretreatment. The VAS score decreased at post-treatment, indicating a reduction of knee pain in this patient. Modified Barthel Index improved at post-treatment, and the patient restored basic community walk after treatment and had an impact on daily life, although walking up and down the stairs were still limited. Our results are consistent with the study of Peeler, in which the VAS, Knee Injury and Osteoarthritis Score (KOOS) questionnaire, and isokinetic strength were evaluated. Peeler's study found that AlterG can effectively reduce knee pain, improve knee function, and increase related muscle strength in OA patients,[5] but Peeler did not assess AlterG's changes in gait patterns and parameters in KOA patients objectively. Also, follow-up evaluation after 4 months showed that the patient's VAS score, 10 MWT, and TUG test were similar to the post-treatment evaluation results, suggesting that the treatment effect could be maintained for more than 4 months.

Our study also introduced 3D gait analysis and surface electromyography as objective assessment methods for this patient. By comparing the changes in kinematics and myoelectric data, the patient's walking capacity and gait pattern were evaluated. The temporal parameter results of this study showed that stride length (% height), mean velocity (%height), and cadence gradually increased before treatment, after treatment, and at 4-month follow-up (Fig. 4),

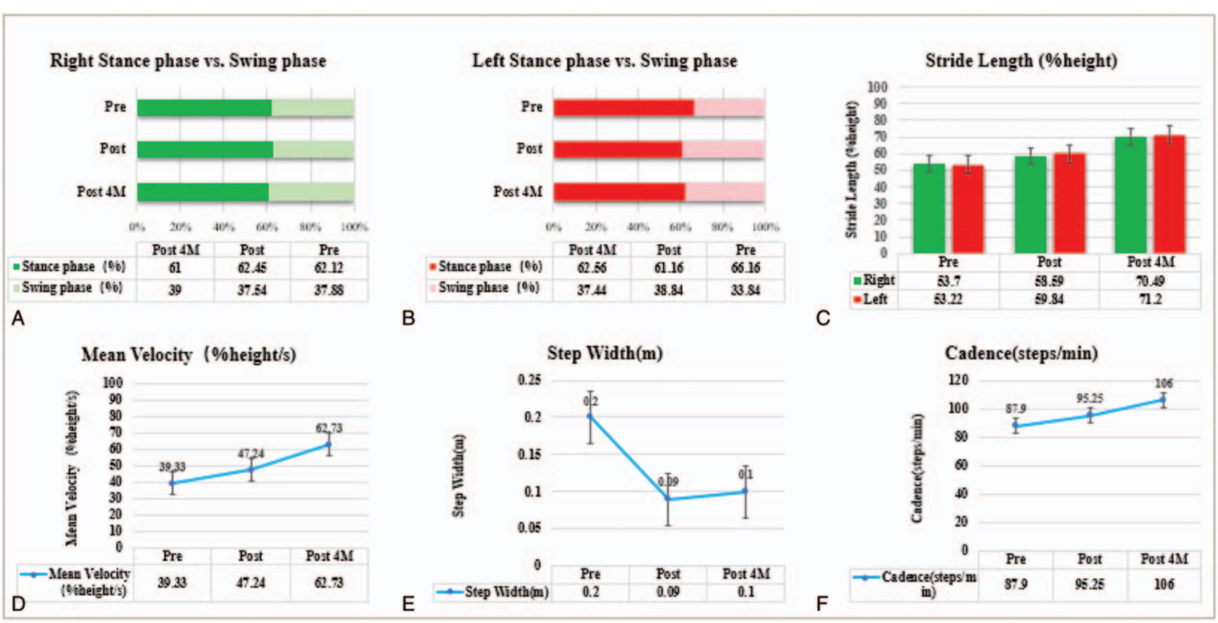


Figure 4. The spatio-temporal parameters of the patient with KOA at pre-, post-treatment and 4 month follow-up. (A) The percentage of right stand phase (dark green) versus swing phase (light green) in gait cycle. (B) The percentage of left stand phase (dark red) versus swing phase (light red) in gait cycle. (C) The stride length (% height) of right side (green) versus left side (red). (D), (E) and (F) show mean velocity (% height/s), step width and cadence respectively. m = meter, min = minute, Pre = pre-treatment, post = post-treatment, post 4M = 4 months after treatment; s = second.

consistent with the results of the 10 MWT and the TUG test. The patient's overall walking capacity was improved, and the effect was maintained until 4 months after treatment; the step width after treatment and at 4 months was significantly lower than before treatment (Fig. 4), suggesting that the patient's gait stability was improved.

Previous studies have not detected an effect of AlterG on the joint kinematic analysis during walking. In this study, the sagittal knee mobility of this patient at pretreatment, post-treatment, and 4-month follow-up were compared with the normal subject (BTS normal subject data for reference) in the gait cycle. The results showed that the right ROM of knee flexion in the swing phase gradually approached the normal ROM, while in the stance phase, the maximum angle of knee flexion gradually increased. The reason for this result could be that the AlterG training mainly affects the swing phase of sagittal knee ROM (Active knee flexion ROM), rather than the standing phase, thereby improving the total ROM of the affected knee joint. Meanwhile, the synchronized EMG data showed that the RMS values of the rectus femoris, semitendinosus, and biceps femoris at post-treatment were improved to different degrees than at pretreatment. Just as notable is that the RMS values of the semitendinosus and the biceps femoris were improved to a greater extent than the rectus muscles (Fig. 5). The above results (knee ROM and EMG data) suggest that AlterG treatment might be aimed by addressing the capacity of active knee flexion during the swing phase and the corresponding knee flexors in the gait cycle, which might also contribute to the recovery of patient community walking ability.

7. Limitation

There are several limitations to this case study. First, the outcomes represent a single case and would need to be replicated

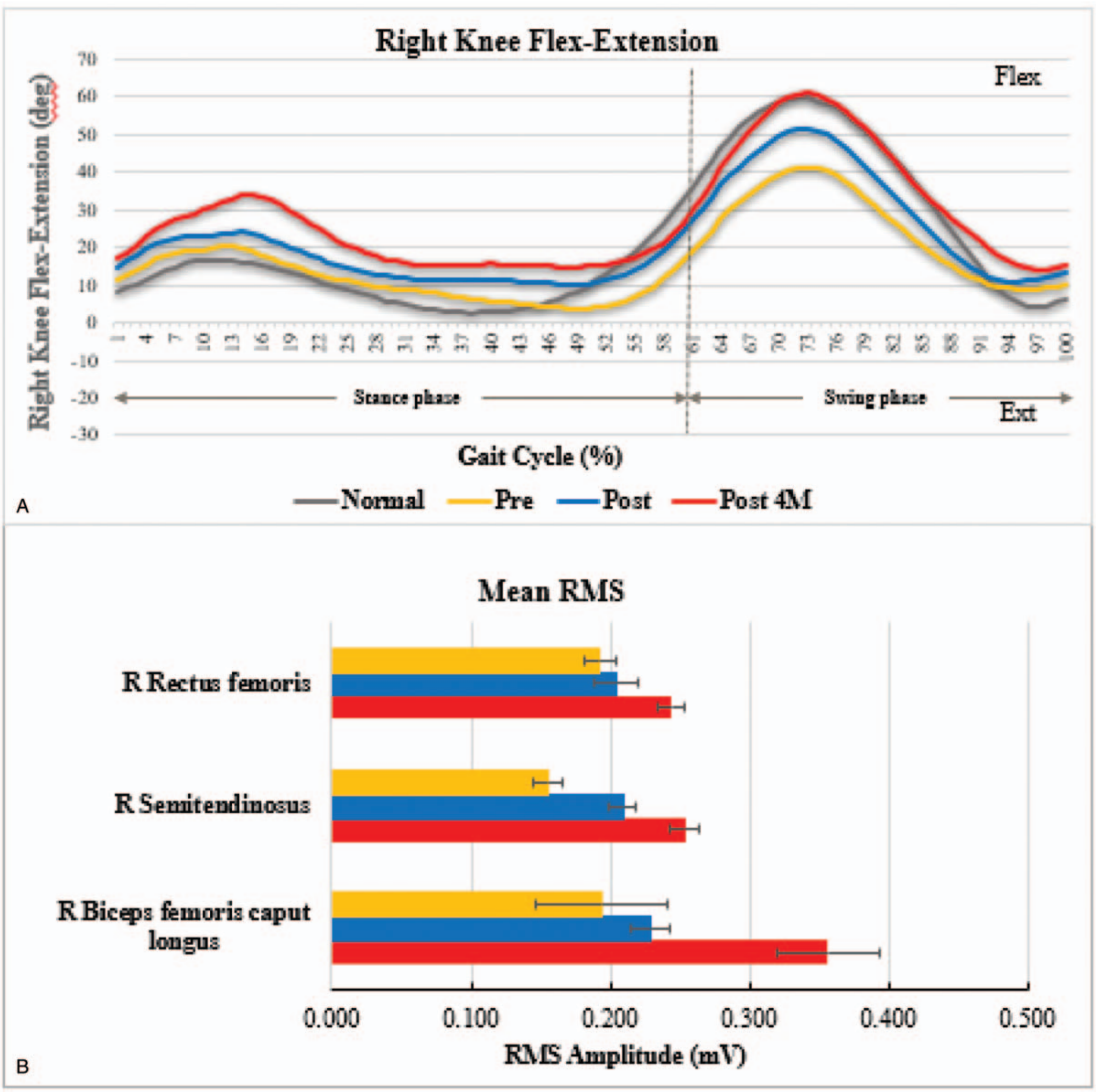


Figure 5. The right ROM of knee flex-extension in gait cycle and the synchronized EMG activity of the patient with KOA at pre-, post-treatment and 4 month follow-up. (A) The knee flex-extension of the patient and (B) shows the synchronized EMG activity of the patient with KOA in gait cycle at pre- (yellow), post-treatment (blue) and 4 month follow up (red). The knee flex-extension reference of normal subject was also showed in (A) (grey). deg = degree, Ext = extension, Flex = flexion, mV = microvolt, pre = pre-treatment, post = post-treatment, post 4M= 4 months after treatment, R = right, RMS = root mean square, s = second.

in a larger sample size to determine the relationship between the intervention and the outcomes. Here, our intention was only to present the model of AlterG treatment protocol for KOA rehabilitation and gave some indications about the potential rehabilitation mechanism for AlterG. Second, the design requirements of the AlterG bag somewhat limit the movement of the upper limbs during the walking training, which might affect the gait parameters in the gait cycle, especially the stance phase. Also, the evaluation of intervention efficacy extended over 4 months follow-up could not exclude the natural recovery of the disease itself.

8. Conclusion

This case study used clinical assessment scales and three-dimensional gait analysis combined with synchronized EMG to evaluate the clinical efficacy of AlterG in the treatment of a knee osteoarthritis patient and the change of gait characteristics. We found that for this patient with KOA, AlterG relieved pain, and was also effective at improving spatio-temporal parameters, knee flexion/extension gait pattern, and corresponding muscle strength, thereby restoring certain community activities.

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Author contributions

Conceptualization: Junjie Liang, Qiang Lin, Haining Ou.
Data curation: Shijuan Lang, Yuxin Zheng, Yujue Wang, Qiang Lin.
Formal analysis: Junjie Liang, Yuxin Zheng, Yujue Wang, Qiang Lin.
Funding acquisition: Haining Ou.
Investigation: Shijuan Lang, Hongxin Chen, Zhiwei Luo.
Methodology: Junjie Liang, Qiang Lin.
Project administration: Qiang Lin, Haining Ou.
Resources: Jinyu Yang, Zhiwei Luo.
Software: Shijuan Lang, Hongxin Chen, Zhiwei Luo, Qiang Lin.
Supervision: Qiang Lin, Haining Ou.
Validation: Jinyu Yang.
Visualization: Jinyu Yang.
Writing – original draft: Junjie Liang, Shijuan Lang, Qiang Lin.
Writing – review & editing: Junjie Liang, Shijuan Lang, Qiang Lin.

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