EFFECTS OF COMPREHENSIVE EXERCISE THERAPY ON KNEE JOINT FUNCTION AMONG OLDER ADULTS WITH KNEE OSTEOARTHRITIS

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This study investigated the effects of comprehensive exercise therapy on knee joint function for older adults with knee osteoarthritis (KOA). Sixty-six older adults with KOA were randomly assigned to either the exercise group (EG), the heat and electrotherapy group (HG), or the control group (CG) to receive an 8-week intervention. Two-way repeated measures ANOVA was used to analyze the data of knee pain, proprioception, angle, moment, and strength. At week8, the EG had decreased pain scores, proprioception threshold, and knee abduction moment, increased flexion angle and extensor strength; the EG showed lower pain scores and greater strength than the HG and CG, and lower proprioception threshold and greater flexion angle than the CG. Comprehensive exercise therapy is indicated for older adults with KOA to improve knee joint function.

KEYWORDS: pain, proprioception, range of motion, strength, knee loading.

INTRODUCTION: Knee osteoarthritis (KOA) is one of the most common chronic degenerative diseases that adversely affect 12% of adults over age 60 years(Lv et al. 2021). The exact ethology of KOA is largely unknown, and biomechanical factor is one of its main risk factors, such as muscle strength, joint loading, and so on. The mechanical load may be a factor leading to cartilage degradation, and the severity of KOA may be related to the load distribution in the medial compartment of the knee joint (Zhao et al. 2007). KOA induces knee pain, stiffness, decreased muscle strength, and reduced proprioceptive sensitivity leading to knee dysfunction that interferes with daily functional activities (Weng et al. 2009). Eighty percent of the patients with KOA over 60 years of age have limited motor function, while 25% have difficulty completing their primary activities of daily living (World Health Organization 2013). Without proper treatment, the older adults with KOA may experience persistent knee joint pain and dysfunction, which may lead to changes in the biomechanics and movement patterns of the lower limbs during daily activity, thereby exacerbating the process of KOA.

Exercise therapy is strongly recommended to treat KOA(Brown 2013). Several protocols have been developed (Wellsandt and Golightly 2018), like strengthening training, aerobic or neuromuscular exercises, which showed positive effects in reducing pain and enhancing muscle strength, but failed to balance load distribution between medial and lateral compartments at the knee. Previous studies indicated that proprioceptive neuromuscular facilitation (PNF) training could decrease the loading of the medial compartment at the knee (Song et al. 2020), but failed to improve active joint range of motion, body stability, and posture control. Single-type exercise therapy may not be adequately effective in improving multifunction disorders of KOA. A customized, comprehensive exercise therapy considering pain, joint range of motion (ROM), muscle strength, proprioception, and mechanical loading may be essential to improve knee function and treat KOA effectively. Therefore, this study aimed to examine the effects of the comprehensive exercise program on knee joint function among older adult with KOA.

METHODS: Eighty-two participants (>65 years) diagnosed with KOA were recruited, and sixty-six of them who were assessed for eligibility (KOA phase graded from 1 to 4) were randomly assigned to three group. The exercise group (EG, age: 67.0±2.7 yrs, BMI: 25.7±2.3 kg/m^2) performed a combination of PNF training + muscle strength training + gait training, the heat and electrotherapy group (HG, age: 67.5±4.4 yrs, BMI: 25.7±3.0 kg/m^2) utilized a combination of heat therapy combined with low and mid-frequency electrotherapy interventions, and the control group (CG, age: 65.7±1.9 yrs, BMI: 27.4±2.1 kg/m^2) attended health lecture series,

such as watching selected TV programs, psychological health education, and so on. Each type of intervention was delivered one-hour per time, three times per week, last 8 weeks. The participants were excluded when their attendance rate was less than 80% during the 8-week intervention. Fifty-six participants were analysed, 18 EG, 20 HG, 18 CG.
Pain, proprioception, joint ROM, and strength data were measured before and after the intervention using a Visual Analogue Scale, proprioception device (Sunny, AP-II, China), goniometer (Zimmer Ltd, Blackpool, UK), and strength testing system (IsoMed 2000, D. & R. Ferstl GmbH, Hemau, Germany), respectively. A motion capture system (Vicon, Oxford Metrics Ltd., UK), synchronized with two force plates (Kistler, 9287BAs Switzerland) was used to collect knee joint and moment data during walking at 100 Hz and 1000 Hz, respectively. The participants were asked to walk at a self-selected pace on a 10-meter simulated walkway.
Forty-one retro-reflective markers were placed on the bony landmarks according to the Vicon plug-in-gait set. Hybrid Model was used to create the model in Visual-3D software (C-motion, Germantown, MD, USA). The joint angles and GRF were filtered with cut-off frequencies of 6 and 40 Hz by a fourth-order, zero-lag, low-pass Butterworth filter, respectively. Peak external knee abduction moment (KAM) in a single support phase was calculated using inverse dynamics and normalized with participant body mass and height (Nm/kg).
Two-way ANOVA with repeated measures was used to determine the effects of time and group on each of variable. A Bonferroni-adjusted post hoc analysis was conducted after the time–group interaction was detected. Partial eta squared (η_p^2) was used to represent the effect size of the main effect and interaction of two-way ANOVA. Cohen's d was used to represent the effect size of the post hoc comparison(Cohen 1988).

RESULTS: In Table 1, significant interactions were detected in pain score, knee flexion ROM and proprioception threshold, knee extensor strength, and the second peak of KAM. Compared to $Week_0$, the EG had decreased pain scores, proprioception threshold, and the second peak of KAM, increased knee flexion ROM and strength at $Week_9$; the HG had decreased pain scores at $Week_9$. Compared to the HG, the EG showed lower pain score and greater strength at $Week_9$; compared to the CG, the EG showed lower pain scores, PT, and greater ROM and strength at $Week_9$.

Table 1: Indicators of the injured leg, presented as mean ± S.D.

	Week	Exercise group (EG, n=18)	Heat and electrotherapy group (HG, n=20)	Control group (CG, n=18)	Interaction P	Interaction η_p^2	Post-hoc P	Post-hoc *d*
Pain (mm)	0	6.27±1.01	5.74±1.39	7.80±1.38	<.001	0.436	a<.001; b<.001; c=.043; d<.001; e=.005.	a=3.13; b=1.04; c=0.84; d=2.10; e=1.01.
	9	2.92±1.15^{a,c,d}	4.13±1.66^{b,e}	8.50±1.37				
Knee flexion ROM (°)	0	111.9±8.3	110.0±7.5	111.1±7.5	.033	0.121	a=.011; c=.049.	a=0.54; c=0.77;
	9	116.5±8.6^{a,d}	111.7±7.7	109.1±10.5				
Knee flexion Proprioception (°)	0	4.05±2.83	4.22±2.69	3.91±2.43	.034	0.120	a=.002; d=.048.	a=0.64; d=0.78.
	9	2.49±1.50^{a,d}	3.48±2.00	4.18±2.66				
Knee extensor strength (Nm/kg)	0	0.90±0.27	0.73±0.25	0.78±0.24	.042	0.113	a=.029.	a=0.47.
	9	1.02±0.24^{a}	0.69±0.28	0.72±0.25				
KAM first peak (Nm/kg)	0	0.40±0.11	0.39±0.13	0.43±0.13	.908	.004	--	--
	9	0.38±0.15	0.36±0.09	0.42±0.11				
KAM second peak (Nm/kg)	0	0.32±0.09	0.30±0.09	0.31±0.09	.036	.118	a=.009.	a=0.84.
	9	0.24±0.10^{a}	0.32±0.12	0.31±0.10				

a / b Denotes significant difference in the EG / HG between $Week_0$ and $Week_9$; c / d / e Denotes significant differences compared with the HG / CG / CG at $Week_9$.

DISCUSSION: Our findings showed that exercise intervention better improves pain, joint ROM, knee flexion proprioception, and knee extensor strength in patients with KOA compared to the physiotherapy and health lecture series.

The results showed pain relief in the exercise group after the intervention and was better than the physiotherapy group. The stretching of PNF in the exercise group may be beneficial for pain relief as it requires the antagonist muscle to implement isometric contraction in the maximum ROM, thereby inducing the inhibitory effect of Golgi tendon organs when the force exceeds the safety threshold as body perception. The gate control theory (Melzack and Wall 1965),one of the well-known theories about pain, states that pressure signals suppress the expression of pain signals, and thus moderately decrease pain.

Compared to healthy older adults, patients with KOA exhibit worse knee flexion proprioception due to articular cartilage degeneration, joint capsule contracture, and muscle atrophy, resulting in proprioceptor damage (Knoop et al. 2011). In this study, exercise intervention improved proprioception in KOA patients, and the mechanism may be: 1. PNF training stimulates proprioceptors, excites sensory nerves and interneurons, reduces muscle tone, and promotes active contraction of the agonist muscle (Sharman, Cresswell, and Riek 2006). 2. isometric resistance exercise on the quadriceps is benefit to increase the sensitivity and coordination of muscle receptor (Topp et al. 2002).

The results of this study showed an increase in extensor muscle strength after the exercise intervention. The mechanism of the exercise intervention to increase muscle strength may be that resistance training facilitates an increase in muscle cross-sectional area and a decrease in muscle fiber density, which increases muscle strength. Animal experiments by Castrogiovanni et al. verified this idea(Castrogiovanni et al. 2019).

Limited joint mobility is one of the common clinical manifestations of KOA (Steultjens et al. 2000). Patients with KOA often present with flexion dysfunction, which leads to difficulties in squatting or stair walking (Kocic et al. 2021). The results of this study showed an increase in flexion ROM in the exercise group after the exercise intervention. PNF stretching and resistance training helped to increase the joint space, which led to an increase in joint ROM(Sharman, Cresswell, and Riek 2006).

Knee abduction moment has been regarded as the "gold surrogate" for indicating the loading at the medial compartment of the knee. It has been suggested that a movement pattern dominated by enhanced joint motion in the frontal plane may contribute to the reduction of knee abduction moment (Gao et al. 2023). Both the spiral diagonal movement pattern of the PNF and the Toe-in gait training in this study had the effect of strengthening the joint frontal plane movement.

During PNF training and toe-in gait training, the ankle underwent a plantarflexion with inversion movement or dorsiflexion with eversion movement (Shen et al. 2021), which was similar to adjusted gait training and reduced KAM by shortening the distance between the knee center and the center of pressure.

Changes in lower limb proprioception, joint ROM, and lower limb muscle strength before and after the intervention in the physiotherapy group were not observed in this study, and we believe that this result can be explained. Whether it is knee joint proprioception, ROM, or muscle strength, they are all closely related to organic structures such as joints, muscles, and ligaments (Dorothy E. Voss 1985), which means that it may be necessary to apply a certain amount of external force to these related structures in order to cause changes. The main effects of physical therapy are to improve blood circulation, promote tissue repair, reduce peripheral nerve sensitivity, and increase pain threshold (Organization 2013). It has been confirmed that the therapeutic effect of physical therapy for KOA lies in the relief of pain (Nazari et al. 2019), with little improvement in other symptoms.

CONCLUSION: This study confirmed that an 8-week comprehensive exercise therapy positively affects KOA treatment by reducing pain and KAM, and improving joint proprioception, ROM, and strength among older adults with KOA. The overall knee joint function level was enhanced.

ACKNOWLEDGEMENTS: This project was funded by the China Scholarship Council (Number 202106520019), and the International Society of Biomechanics Council (Student Matching Dissertation Grant)

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