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A Preliminary Study Into the Effect of 2 Resistance Training Modes on Proprioception of Subjects with Knee Osteoarthritis

Robert Topp,[1*] and Matthew Pifer[2]

Background: Osteoarthritis (OA) of the knee is a common health problem accompanied by pain and functional declines. Resistance training can reduce pain and functional declines and may also improve proprioception of the OA-affected knee.
Purpose: The purpose of this study was to compare changes in proprioception among adults with knee OA who underwent 16 weeks of dynamic or isometric resistance training with those in control.
Study Design: This study is a 3-group test–retest clinical trial.
Methods: In total, 69 community-dwelling subjects completed proprioception assessments of both knees at baseline and following 16 weeks of their respective intervention. At baseline, subjects were asked to identify the knee that they considered as their more affected or painful side. Subjects were then randomized into a nonexercise control (n = 23), a dynamic resistance training group (n = 23), or an isometric resistance training group (n = 23). Exercise subjects participated in dynamic or isometric resistance training of the lower limbs using TheraBand® elastic resistance 3 times per week.
Measures: Proprioception protocols assessed the time to detect passive movement and the ability to passively reposition the knee joint.
Results: ANCOVA determined if changes in proprioceptive ability between baseline and the 16-week retest were different between any of the 3 study groups while using the baseline measures as a covariate. The isometric resistance group exhibited a 36% improvement in their time to detect passive movement of their more affected knee compared with the control group. The dynamic resistance training group showed a 19% improvement in passive repositioning of the knee joint of their more affected knee compared with the control group. Both the resistance training group did not show a change in proprioception in their less-affected knee compared with the control group.
Conclusions: These findings appear to indicate that both dynamic and isometric resistance training may improve proprioceptive functioning among subjects with knee OA.

Keywords: Resistance training; proprioception; osteoarthritis; knee

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Key Point: Resistance training with TheraBand® exercise bands improves proprioception in subjects with knee osteoarthritis.

Osteoarthritis (OA) is the most common joint disorder in the USA.[1] Among adults ≥60 years of age, the prevalence of symptomatic knee OA is ~10% in men and 13% in women.[2] OA is the second most common cause of disability among older adults, with the lifetime costs to manage knee OA estimated to be $140,300.[3] When disease symptoms affect the knee, it results in a limited ability to use stairs, get up from a chair, stand comfortably, walk, or complete activities of daily living.[4]

Changes in the neuromuscular systems surrounding an OA-affected knee joint have been observed. Numerous investigators have reported that quadriceps' strength decreases in the OA-affected knee early during disease progression.[5] This decline in strength has, in the past, been assumed to be associated with disuse observed among subjects with knee OA because of their joint pain apparently limiting their physical activity. This assumption that declines in quadriceps strength are because of disuse due to knee pain that is exacerbated with activity has been challenged. Slemenda et al.,[6] reported that quadriceps' strength in the OA-affected knee declines, whereas that in the hamstrings of the same knee is preserved. This finding indicated that disuse is not a direct contributor toward declines in quadriceps' strength among subjects with knee OA. This conclusion is consistent with that found by other investigators who reported quadriceps' weakness among subjects with OA early in the progression of their disease, possibly before the effect of disuse could have affected quadriceps' strength.[7] Thus, it appears that pain and disuse may not be the only factors contributing to the declines in quadriceps' strength among subjects with knee OA. Rather, the declines in quadriceps' strength and the symptoms of knee OA may be because of other events,[8] including swelling within the capsule or changes in the motor and sensory functions in the muscles surrounding the knee.[9]

Numerous neurological structures contribute to the proprioception of the knee joint. Proprioceptive receptors provide information regarding position and movement sense. Proprioceptors within the knee joint capsule include Pacinian corpuscles, Ruffini receptors, and free nerve endings.[10] Proprioceptors outside of the knee joint capsule include Golgi tendon organs and muscle spindles in the muscles and ligaments controlling the knee, which respond to changes in the length of muscles and ligaments. These proprioceptors outside of the knee joint in the muscle are considered as the important components of the proprioceptive system.[11]

Previous investigators have used various techniques to report declines in proprioceptive sensitivity among subjects with knee OA. These techniques assessed time to detect passive movement (TTDPM) and the ability to passively reposition the knee joint (PRP). TTDPM techniques measure the differences in the degrees of joint movement between the onset of motion and the subject's ability to detect the motion.[12] This test appears to selectively test Ruffini- and/or Golgi-type receptors.[13] Tests that assess PRP involve the subject's ability to passively reposition the knee to a specific knee joint angle. Passive reposition tests seem to be selectively dependent upon proprioceptors within the muscles.[14]

Sharma et al.,[15] compared the ability of subjects with unilateral OA of 1 knee with that of non-OA controls to detect knee extension from 45° of flexion at a test speed of 0.3° per second. These investigators reported a significant deterioration in TTDPM ability in both knees of subjects with OA compared with that in the controls and found no

difference in the proprioceptive ability when comparing the knees of the OA sample.[15] This decline in TTDPM ability among subjects with bilateral knee OA with unilateral symptoms when compared with age-matched controls has been reported by numerous previous authors.[10,16] Differences between OA and non-OA samples using a PRP test have also been reported.[17] Hurley et al.,[18] reported significant deficits in knee joint angle reproduction in subjects with bilateral knees OA with unilateral disease when compared with healthy age-matched controls. Garsden and Bullock-Saxton[19] replicated these findings using a technique to measure knee joint angle reproduction under partial weight-bearing conditions. These studies indicate that knee joint proprioception measured using TTDPM and PRP techniques is less precise in both knees among subjects with either unilateral or bilateral knee OA.

A substantial number of investigators have indicated that various exercise interventions can reverse declines in strength and physical functioning and also reduce knee pain among subjects with knee OA. One of the first large trials in the area (Fitness Arthritis and Senior Trial) indicated that long-term walking or strength training improves functional ability and gait and reduces postural sway and knee joint pain among subjects with knee OA.[20] Other investigators have consistently found similar beneficial effects of various exercise interventions introduced for subjects with knee OA.[21,22] A number of comprehensive reviews in the area have made similar conclusions regarding the benefits of exercise among subjects with OA.[23–25]

In addition to reducing knee joint pain and improving functioning of subjects with knee OA, regular exercise also appears to improve neural functioning of muscles involved during training. Taaffe et al.,[26] reported that performing resistance exercise once every week appeared to not only improve function and reduce pain but also improve neuromuscular performance among older adults. Gains in strength because of resistance training could be attributed to neural adaptations including improved coordination and firing patterns.[27] In a study that compared resistance training, proprioceptive training, and a control group, the resistance training group demonstrated improved strength, while the proprioceptive training group demonstrated the greatest gains in balance control.[28] These investigators concluded that the proprioceptive training and possibly resistance training improved somatosensory inputs resulting in improved balance. In one of the early studies in the area, proprioception improved with dynamic resistance training.[29] Lin et al.,[30] reported that proprioceptive training improved position sense, and that resistance training improved strength among subjects with knee OA. No study has compared isometric with dynamic resistance training on knee proprioception of adults with knee OA. Such a study may indicate the impact of these 2 types of resistance training on proprioception. Thus, the purpose of this study is to compare changes in proprioception among adults with knee OA following either 16 weeks of dynamic or isometric resistance training or control condition. This purpose generated 2 hypotheses:

H1. Changes in proprioception in the more affected knee of subjects with knee OA following either 16 weeks of dynamic or isometric resistance training with elastic bands will be greater than changes in proprioception following 16 weeks of a control condition.

H2. Changes in proprioception in the less affected knee of subjects with knee OA following either 16 weeks of dynamic or isometric resistance training with elastic bands will be greater than changes in proprioception following 16 weeks of a control condition.

METHODS

This study was approved by the institutional review board of the Medical College of Ohio. In total, 69 community-dwelling male (n = 18, 26%) and female (n = 51, 74%) subjects previously diagnosed with knee OA

volunteered and completed the 16-week protocol. These subjects were recruited from physician offices, local senior centers, and local arthritis support groups. Subjects were included if during an initial telephone interview, they reported a moderate degree of knee pain due to OA as evidence of a score on the Western Ontario and McMaster University Osteoarthritis Index (WOMAC) pain subscale of 5 or greater. The WOMAC is a multidimensional, disease-specific, self-administered health status instrument for subjects with hip and knee OA.[31] The WOMAC is composed of 3 subscales including perceived pain, stiffness, and functional ability. The subjects completing the instrument rates their perceived pain, joint stiffness, and functional ability on a 5-point (none, slight, moderate, severe, extreme) Likert scale, which is scored from 0 to 4. The scores for each dimension were determined by summing the items contributing to each of the subscores. Higher scores on these subscales indicated higher degrees of joint pain, joint stiffness, and functional limitations. Bellamy et al.,[31] reported acceptable reliability coefficients (Cronbach's alpha ≥ .85) for all of the WOMAC subscales. Construct validity of the WOMAC was considered acceptable compared with that of other instruments that measured pain, stiffness, physical capacity, and joint tenderness.[32] A physician validated the knee pain and diagnosis of knee OA using previously established criteria,[33] during a history and physical examination. Potential subjects were excluded if they exhibited any contraindications for exercise, including a history of uncontrolled angina; cardiomyopathy severe enough to compromise cardiac functioning; electrolyte or metabolic disturbances; disabilities that prohibited strength training of the lower extremities; or if they were currently taking nitrates, digitalis, or phenothiazine. Subjects were also excluded if they were participating in an organized exercise program or exercised more than 1 hour every week. Of the participants who volunteered for the study, 100 were initially randomized into the treatment groups and 69 (69%) completed the entire study protocol. A majority of the 31 subjects who dropped out of the study claimed lack of time as the reason for not completing the study protocol.

Subjects who were not excluded during the initial telephone interview were invited to complete a background/demographic questionnaire, and they underwent a history and physical examination, including an EKG. Before any testing, each subject completed a written informed consent that was approved by the University's institutional review board. Subjects were excluded from further participation if their history, physical examination, or EKG indicated that they may have difficulty with the testing procedures or if they were found to complain of knee pain due to a cause other than OA, including fibromyalgia, bursitis, tendentious, or a tear of the articular cartilage of the knee or pain in the lower back, hips or ankles. Those who were eligible for the study completed a background questionnaire and 2 assessments of their knee proprioception bilaterally before being randomized into the treatment groups. Subjects again completed these assessments following 16 weeks of participation in their respective treatment group. In addition, subjects were asked to identify which of their knees was more "painful or affected or gave them more trouble". The side the subject identified was then considered as their more affected side. If the subject claimed to have pain in both knees, they were asked to identify the side that caused them the most pain or discomfort. The side identified by the subject was considered their more affected side even though both sides may have exhibited OA symptoms. No attempt was made to discriminate subjects with unilateral OA from those with bilateral OA. Staging the subject's grade of OA severity on the basis of radiological reports was not completed because of the reported low correlation between radiological findings of knee OA and the patient's functional ability and reported level of knee pain.[34]

Assessment of knee joint proprioception was performed on both legs by adapting the protocol described previously.[35] These protocols assessed both TTDPM and PRP. Subjects were seated and reclined to attain 60° of hip flexion. The lower legs hung freely over the side of a firm seat, with the popliteal fossa being 4–6 cm from the edge of the seat. A custom-made JOBST® air splint (Charlotte, NC) was fitted to the subject's lower leg just below the knee and inflated to 20 mmHg to neutralize cutaneous sensation. A wire attached to the tip of the leg air splint accomplished movement of the extremity. The wire was attached through pulleys to a low-speed motor. The position of the pulleys and motor was adjusted to ensure that the wire through its natural arc of extension pulled the lower leg. For the TTDPM test, a starting position of 60° of knee flexion, as measured by a goniometer, was used to minimize the pull of gravity on the apparatus. Subjects were blindfolded during the procedure to eliminate visual cues. Subjects were given a handheld on/off switch, and were asked to turn the switch off at the first instant they recognized a change in the position of their knee. This switch operated the motor, and when depressed, stopped the motor and held the knee at the new angle of extension. Subjects were told that their knee would begin to be extended within 30 seconds after the motor begins working. At random intervals between 0 and 15 seconds, the investigator engaged the motor and began moving the wire through the pulleys and extending the knee at a speed of 0.4°/second. Once the subject detected knee extension and turned the motor off, the linear movement of the wire was measured in millimeters and converted to angular deflections expressed in degrees of movement. Five repetitions of the protocol were completed. The sum of these 5 trials was then calculated for each knee, with greater numbers indicating lower proprioceptive ability. Skinner et al.,[35] supported the validity of this measure of knee joint proprioception by correlating it with a reproducibility of joint angle measures ($r = .29$, $P < .03$).

The PRP test was performed while the subject was positioned in the same apparatus as the TTDPM, but starting with the knee in 90° of flexion. The examiner extended the knee by pulling on the wire using the slow-speed motor connected to the air splint at a constant speed of 10°/s to 30°. Subjects were told to allow their knee to move passively. The knee was held at 30° of flexion for 4 seconds and the subject was asked to concentrate on the position at which their knee has been placed. The knee is returned to the 90° starting position and the subject was blindfolded. The examiner begins by extending the knee using the apparatus at a constant speed of 10°/s. The subject was instructed to stop the motor on the apparatus with a handheld button once their knee reached the 30° position on which they were first asked to concentrate. The absolute difference in degrees of extension between the subject's perception and the actual 30° of flexion target was recorded. The sum of 5 trials of this protocol was then calculated for each knee, with greater numbers indicating lower proprioceptive ability.

Following baseline testing, subjects were randomly assigned to 1 of the following 3 treatment groups: dynamic resistance training (DYNAMIC), isometric resistance training (ISOMETRIC), or a no intervention group (CONTROL). Subjects assigned to the 2 resistance training groups began their respective treatments, documenting their exercise compliance on the first day of the week following their baseline testing. Both resistance training interventions trained the same 6 muscle groups of the legs, that is, ankle plantar-/dorsiflexors, knee extensors/flexors and hip extensors/flexors. All resistance training occurred bilaterally, with both resistance training interventions exposing the subjects to the same time under tension and rest during each exercise session. Both interventions of resistance training included the same scheduled increases in repetitions and sets over the 16-week training protocol. Subjects who were able to document a 70% compliance

with their respective training protocol were included in the final analysis.

The DYNAMIC group was given a strength training booklet that explained 6 resistance training exercises using TheraBand® elastic bands (Performance Health, Akron, Ohio). The dynamic resistance training booklet was based upon a previously described resistance training protocol that used TheraBand elastic bands and was found to result in significant improvements in leg strength following 12 weeks of training.[36] The booklet described the warm-up, strength training and cool-down components of a session of resistance training. Resistance training using TheraBand elastic bands as the mode of resistance was selected for 2 reasons. First, previous work in the area indicated that the minimum weight on standard universal weight training machines was in excess of some of the subjects' initial strength capacity. In addition, a pilot study indicated that the weight increments on the universal weight machines were too great to yield a smooth progression of training among a sample of subjects with OA. The second reason TheraBand elastic bands were selected is that this mode of resistance training allows the subjects to continue training if they are unable to attend the supervised resistance training classes. Dynamic resistance training using elastic bands also provided progressive resistance to the muscle group over a functional range of motion. Subjects were requested to complete the 6 muscle strengthening exercises bilaterally 3 times per week. Two of these weekly exercise sessions took place unsupervised in the subject's home with 1 session per week under the supervision of the project staff in an organized class. Subjects recorded their compliance with this prescribed exercise in an exercise log. The exercise log was verified by the exercise leader following each supervised session of resistance training.

Initially, a session of dynamic resistance training included a 5-minute warm-up, 30 minutes of dynamic resistance training, and 5 minutes of cool-down. The warm-up consisted of mild un-weighted leg movements. Following the warm-up, subjects completed the 6 dynamic resistance training exercises bilaterally that were designed to develop the ankle dorsi-/plantarflexors, knee flexors/extensors, and hip flexors. During training weeks 1 and 2, each subject performed 1 set of 8 repetitions of each exercise using a band of sufficient resistance to result in a rating of perceived exertion of "mild" fatigue following 8 repetitions. Subjects increased the number of repetitions and/or sets of repetitions every week in a scheduled progression of training outlined in their exercise booklets. Progression of training continued until during weeks 9–16; each subject completed 3 sets of 12 repetitions of each exercise with a TheraBand elastic band of sufficient thickness to result in a rating of perceived exertion of "moderate" fatigue following each set of 12 repetitions with a 2-minute rest between sets (~50 minutes). The cool-down consisted of 5 minutes of stretching exercises.

The ISOMETRIC group was given a strength training booklet that explained the 6 resistance training exercises using standard isometric training techniques. These isometric resistance training techniques required the subjects to generate tension in the muscle without changing the joint angle. Subjects generated this muscle tension using maximum-resistance (gold color) TheraBand elastic bands that they were unable to stretch during the exercise. Subjects performed the 6 isometric resistance training exercises bilaterally 3 times per week while positioning the targeted muscle and joint at a predetermined joint angle. After positioning the joint to the prescribed angle, the subject generated tension against the elastic bands in the muscle group for 3–5 seconds without moving the joint angle. Training joint angles included 0° of dorsi-/plantarflexion when performing ankle dorsi-/plantarflexion of the ankle, 10° of knee flexion when performing knee flexion and extension, and 10° of hip flexion and 10° of hip extension when performing the 2 hip resistance training exercises. During training weeks 1 and 2, each subject performed 1 set

of 8 repetitions while producing "mild" or "submaximum" muscle tension during the exercise. Following these first 2 weeks, each subject was told to complete each isometric repetition while producing "maximum" muscle tension for 3–5 seconds. This intensity of training was designed to result in a "moderate" degree of muscle fatigue following the final repetition of the set for each exercise. Subjects increased the number of repetitions and/or sets of repetitions every week in a scheduled progression of training outlined in their exercise booklets. Progression of training continued until weeks 9–16, during which each subject performed 3 sets of 12 repetitions of each exercise with a 2-minute rest between sets (~50 minutes). The cool-down period consisted of 5 minutes of stretching exercises. Two of these weekly exercise sessions took place unsupervised in the subject's home, with 1 session per week under the supervision of the project staff in an organized class. Subjects recorded their compliance with this prescribed exercise in an exercise log. The exercise log was verified by the exercise leader following each supervised session of resistance training.

The CONTROL group subjects were not given any intervention between baseline testing and the 16-week posttest. The decision to develop a no-intervention control group was based on the possible positive effect that even minor amounts of placebo-type activity interventions may have upon severely detrained older adults. As an incentive to remain in the study, all control group subjects were offered 2 weeks of either isometric or dynamic resistance training after their 16-week posttest. Controls were told not to change the usual amount of activity they engaged in before beginning the project.

The analysis was performed in 2 steps. First, inferential statistics were used to compare the groups at baseline on background characteristics (Table 1). The second step in the analysis was directed at addressing the hypotheses. Because the sample showed a high degree of variability on all of the measures of proprioception 2 strategies were used to minimize the effect of this variability. First, change scores were calculated for each subject on each of the 4 measures of proprioception. These change score were calculated by subtracting the subjects's 16-week retest from their score baseline score. Positive change scores indicated improved proprioceptive ability at the 16-week retest over the measures exhibited at baseline. The second method of reducing the effect of variability in the data was to determine if the 3 study groups differed on these change scores by using analysis of covariance (ANCOVA). Difference scores in the 4 measures of proprioception were compared between the 3 treatment groups using univariate analysis while using the respective baseline proprioceptive measure as a covariate. Each of these covariates accounted for a significant amount of the variance in each of the ANCOVA models (Tables 2 and 3) and thus reduced the amount or variance in the model that was attributed to error. Group effects were further examined using Tukey's least significant difference post hoc test at the .05 level of significance.

RESULTS

The first analysis involved comparing baseline characteristics between the DYNAMIC, ISOMETRIC and CONTROL groups (Table 1). Following this initial step, ANCOVA was performed to determine if either of the treatment group's proprioception change scores differed from the control group's proprioception change scores while controlling for their baseline proprioceptive measure (Tables 2 and 3). Table 1 indicates that both groups exhibited similar distributions in gender and similar ages, weights, number of chronic conditions, and number of prescribed medications taken on a regular basis, and in similar measures of pain, stiffness, and functioning based upon the WOMAC instrument. Tables 2 and 3 present the analyses that address the study hypotheses. Table 2 presents data

Table 1. Comparisons of baseline characteristics between Dynamic (*n*=23), Isometric (*n*=23) and Control groups (*n*=23)

Variable	Dynamic n (%)	Isometric n (%)	Control n (%)	df	Chi Square	*P*<
Gender						
Male	6 (26%)	9 (39%)	5 (22%)	2	1.83	0.4
Female	17 (74%)	14 (61%)	18 (78%)			

	Unadjusted Means			ANOVA Table				
Variable	Dynamic Mean ± SE	Isometric Mean ± SE	Control Mean ± SE	Source	df	Mean Square	F	*P*<
Age	65.22 ± 2.34	63.48 ± 2.19	58.83 ± 2.81	Between	2	251.16	1.8	0.17
				Within	66	139.2		
Body Weight (lbs)	198.1 ± 8.4	200.9 ± 9.5	193.5 ± 10.7	Between	2	316.54		
				Within	66	2102.12	0.15	0.86
Number of Chronic Conditions	2.2 ± .31	2.2 ± .22	2.3 ± .25	Between	2	0.06	0.04	0.96
				Within	66	1.59		
Number of Prescribed Medications	2.0 ± .28	1.5 ± .25	1.3 ± .22	Between	2	3.14	2.12	0.13
				Within	66	1.48		
WOMAC Pain	12.0 ± .72	11.6 ± .55	11.4 ± .65	Between	2	2.29	0.24	0.79
				Within	66	9.54		
WOMAC Stiffness	5.5 ± .33	5.0 ± .35	5.4 ± .35	Between	2	1.95	0.71	0.5
				Within	66	2.76		
WOMAC Function	41.70 ± 1.85	36.48 ± 2.1	39.0 ± 2.30	Between	2	156.55	1.54	0.22
				Within	66	101.13		

concerning the proprioceptive measures of the more affected knee of the 3 study groups, including the unadjusted means at baseline and at the 16-week retest, and the mean and percentage difference change scores. Table 2 also presents ANCOVA tables, which indicate the effect of the baseline values (covariate) and the group assignment on the specific proprioceptive measures. This table indicates that the isometric group significantly improved their ability to detect passive movement of their knee (TTDPM) by 36% over the change exhibited by the control group (9%). The dynamic group exhibited a non-significant change in this score (28%) in the hypothesized direction. Table 2 also indicates that both the dynamic and isometric groups exhibited a non-significant change in their ability to PRP in the hypothesized direction by 19% and 15%, respectively. Post hoc analysis indicated that this change exhibited by DYNAMIC was significant greater than CONTROL (−14%) ($P = .00$).

Similarly, Table 3 presents data concerning the proprioceptive measures of the less affected knee of the 3 study groups, including the unadjusted means at baseline and at the 16-week retest, and the mean and percentage difference change scores. This table also presents ANCOVA statistics that indicate the effect of the baseline values (covariate) and the group assignment on the specific proprioceptive measures. Table 3 indicates that the baseline measures were significantly correlated with the changes scores for each of the measures of proprioception. This table also indicates that the 2 treatment groups changed their proprioceptive measures in the

Table 2. Comparison of changes in proprioception in the more affected knee between dynamic (*n*=23), isometric (*n*=23), and control groups (*n*=23)

	Unadjusted Means			ANCOVA Table				
	Baseline Mean ± SE	16-week retest Mean ± SE#	Mean Change (% of Baseline)*	Source	df	Mean Square	*F*-value	*P* <
Sum of 5 trials to detect movement (TTDPM) (degrees)				Covariate (baseline score)	1	1929.70	139.64	.00
Dynamic	11.77 ± 1.71	8.53 ± 0.70	3.24 (28%)[ab]					
Isometric	11.00 ± 1.34	7.06 ± 0.66	3.94 (36%)[b]	Group	2	44.37	3.21	.04
Control	10.73 ± 1.62	9.76 ± 0.90	0.97 (9%)[a]	Error	65	13.82		
Sum of 5 trials to Reproduce 30° of Flexion (PRP) (degrees)				Covariate (baseline score)	1	1272.41	81.36	.00
Dynamic	11.21 ± 1.10	9.11 ± 0.81	2.10 (19%)[b]					
Isometric	11.22 ± 0.83	9.50 ± 0.61	1.72 (15%)[ab]	Group	2	37.91	2.42	.09
Control	9.99 ± 1.24	11.35 ± 1.01	−1.36 (−14%)[a]	Error	65	15.64		

Note: #SE = Standard error; *means with dissimilar corresponding letters are significantly different according to Tukey's least significant difference (LSD) post hoc test (α = .05).

hypothesized direction, although the magnitude of this change was not significantly different than the change exhibited by the control group.

DISCUSSION

These findings lend support for the first hypothesis that 16 weeks of resistance training using elastic bands will increase knee proprioception in the more affected knee of subjects with OA of the knee. Evidence supporting this hypothesis includes the isometric group showing a significant improvement in their ability to detect passive movement (TTDPM) over the change exhibited by the control group on this measure. Further evidence supporting this hypothesis is the observation that the improvements in the dynamic group's ability to PRP were significantly greater than the change in this variable exhibited by the control group. Finally, this hypothesis is supported by the observation that both the isometric and dynamic groups exhibited a consistent positive trend in changing the proprioceptive functioning in their more affected knee (15%–36%). The control group did not exhibit a consistent trend in their proprioceptive change scores in their more affected knee (−9% to 14%).

These positive findings in the more affected knee are in contrast to the nonsignificant findings that do not appear to support the second hypothesis that 16 weeks of resistance training using elastic bands will increase knee proprioception in the less affected knee of subjects with OA. Table 3 indicates that neither the dynamic nor the isometric group exhibited changes in their proprioception over the changes exhibited in the control group over the duration of the study. However, a non-significant trend did exist in these data,

Table 3. Comparison of changes in proprioception in the less affected knee between dynamic (*n*=23), isometric (*n*=23), and control groups (*n*=23)

	Unadjusted Means			ANCOVA Table				
	Baseline Mean ± SE	16-week retest Mean ± SE#	Mean Difference: (% of Baseline)*	Source	df	Mean Square	*F*-value	*P* <
Sum of 5 trials to detect movement (TTDPM) (degrees)				Covariate (baseline score)	1	945.57	99.54	.00
					2	3.17	0.33	.72
					65	9.50		
Dynamic	10.15 ± 1.14	6.89 ± 0.78	3.26 (32%)[a]					
Isometric	10.21 ± 1.42	6.82 ± 0.69	3.39 (33%)[a]	Group	1	1	1	1
Control	11.04 ± 1.48	7.85 ± 1.04	3.18 (29%)[a]	Error	1	1	1	1
Sum of 5 trials to Reproduce 30° of Flexion (PRP) (degrees)				Covariate (baseline score)	1	1180.55	47.01	.00
Dynamic	11.41 ± 1.26	9.11 ± 0.81	2.30 (20%)[a]					
Isometric	11.82 ± 1.01	9.89 ± 0.75	1.93 (16%)[a]	Group	2	24.15	0.96	.39
Control	12.44 ± .96	11.35 ± 1.01	1.09 (9%)[a]	Error	65	25.11		

Note: #SE = Standard error. *means with dissimilar corresponding letters are significantly different according to Tukey's least significan difference (LSD) post hoc test (α = .05).

indicating the exercise groups positively changed both of their proprioception measures to a greater degree than the control group changed on these measures over the duration of the study.

There are a number of possible explanations for the positive impact of the interventions on the proprioception in the more affected knee of subjects with OA. Previous investigators have reported resistance training in subjects with knee OA improves their functional ability and gait characteristics and reduces postural sway and knee joint pain.[22–25] Thus, it may be postulated that the same mechanism that contributes to these positive outcomes because of resistance training among subjects with OA also contributes to improvements in proprioception. Strength gains because of resistance training are not only from muscle hypertrophy but also from increased muscle activation and coordination by the nervous system.[26,27] Possibly, the gains in proprioception observed because of resistance training can be attributed to adaptations in the nervous system occurring independently or in synergy with increases in strength because of resistance training, which may occur through 2 mechanisms. First, resistance training increases muscle strength, which may increase the sensitivity of the proprioceptive structures outside of the knee capsule, including Golgi receptors and muscle tendon organs. Second, increases in muscle strength resulting from resistance training may attenuate the loading forces experienced through the joint with weight-bearing activities. With fewer forces being absorbed by the joint resulting in less pain, activation of the α-motor neuron may be more coordinated because of lack of inhibition from the joint pain receptors,[37] resulting in more effective functional movements.

Improvements in proprioception, which were reported previously among this sample

of subjects with knee OA because of resistance training, may possibly contribute to improvements in functioning.[22] Skinner et al.[35] hypothesized that declines in proprioceptive sensitivity among subjects with OA was due in part to disease-related destruction of sensory receptors in the affected joint. Resistance training improves strength and may also increase proprioception of the joint involved in the training, which facilitates appropriate coordination of the muscles during a functional activity. Increased proprioception may provide better coordination of the eccentric contraction of the quadriceps during walking to attenuate the forces being transmitted through the knee joint. The subjects who participates in resistance training may be able to maintain normal gait characteristics because of better utilization of the quadriceps during gait owing to better proprioception from the knee joint. This normal gait pattern may minimize joint loading, reduce joint pain, and reduce the likelihood of falls and injuries associated with abnormal gait characteristics.

The observation that the resistance training interventions did not affect the proprioception in the less affected knee of the sample may be attributed to a number of phenomena. First, the progression of the disease in the less affected knee may not be severe enough to contribute to measurable declines in knee proprioception. This explanation is supported by the observation that at baseline, the measures of proprioception in the more affected knee appear greater than the same measures in less the affected knee within both of the intervention groups. If the less affected knee had better proprioception at baseline, it may not be as amenable to the resistance training intervention. Second, the sample was not dichotomized into subjects with unilateral or bilateral OA disease of the knee(s). Subjects with unilateral disease may not exhibit declines in proprioception in the less affected knee at baseline and thus would not respond with improvements in proprioception in the less affected knee because of resistance training.

These findings must be interpreted cautiously because they are susceptible to a number of threats to validity. The small sample showed a high degree of variability on all of the measures of proprioception. Post hoc power analysis indicated that effect sizes in the more affected knee ranged from 0.39 to 0.40 for the TTDPM and PRP within the dynamic group and from 0.61 to 0.43 for the TTDPM and PRP within the isometric group. Thus, with a sample size of 23 per study intervention group, statistical power of the ANCOVA ranged from 0.57 to .88 and from 0.58 to .64 to detect a significant difference in the TTDPM and PRP, respectively. Future researchers studying a larger more homogenous sample may address the variability in these outcome measures. Future researchers may also study only subjects with unilateral or bilateral knee OA, and attempt to rank the severity of the OA in each knee. Another limitation of this study was that the subjects that volunteered were relatively healthy and willing to participate in 16 weeks of resistance training. These characteristics do not describe all subjects who exhibit knee OA. Finally, the clinical implications of resistance exercise improving proprioception from 19% to 36% in the more affected knee among subjects with OA of the knee are yet to be determined but could have a potentially significant impact on improving gait characteristics and reducing falls injuries.

CONCLUSION

Subjects with knee OA who participated in either isometric or dynamic resistance training exhibited improvements in measures of proprioception in their more affected knee over the nontraining control group. Neither of the 2 resistance training groups showed a change in proprioception in their less affected knee compared with the control group. These findings indicate that both dynamic and isometric resistance training may improve

proprioceptive functioning among subjects with knee OA.

Future studies need to determine what portion of improvements in functional ability can be attributed to gains in proprioception or gains in muscle strength that result from resistance training. These findings may indicate the origin(s) of knee OA as being from declines in joint function, muscle strength, or proprioception, and may indicate the most appropriate interventions to prevent and treat this disease.

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