Effect of Bracing on Patellofemoral Joint Stress While Ascending and Descending Stairs

Christopher M. Powers, PhD, PT,† Samuel R. Ward, PhD, PT,‡ Yu-Jen Chen, MS, PT,* Li-der Chan, MS, PT,* and Michael R. Terk, MD**

Objective: To test the hypothesis that individuals who respond favorably to bracing will exhibit decreased patellofemoral joint stress during stair ambulation.

Design: A repeated-measures, cross-sectional study.

Background: Ascending and descending stairs is one of the most painful activities of daily living for persons with patellofemoral pain (PFP). Although patellar bracing has been shown to reduce symptoms during such tasks, the underlying mechanism has not been identified.

Methods: Fifteen subjects with a diagnosis of PFP completed 2 phases of data collection: (1) magnetic resonance imaging to determine patellofemoral joint contact area, and (2) gait analysis during stair ascent and descent. Data were obtained under braced and non-braced conditions. Variables obtained from both data collection sessions were used as input variables into a biomechanical model to quantify patellofemoral joint stress.

Results: Although subjects reported an average decrease in pain of 56%, bracing did not reduce peak stress during stair ascent and descent. This finding can be explained by the fact that despite improvements in contact area, bracing resulted in greater knee extensor muscle moments and joint reaction forces.

Conclusions: Our results do not support the hypothesis that individuals with PFP would demonstrate reduced patellofemoral stress during stair ambulation following the application of a patellar brace.

Clinical Relevance: Although bracing did not decrease patellofemoral joint stress during stair ascent and descent, the decrease in pain, increase in quadriceps utilization, and tolerance of joint reaction forces would appear to be beneficial consequences of bracing.

Key Words: patella, patellofemoral, biomechanics, stress, stairs, bracing

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Patellofemoral pain (PFP) is one of the most prevalent clinical problems involving the lower extremity.[1–5] The onset of PFP is typically insidious and progressive in nature, with symptoms being described as a diffuse ache originating from the retropatellar region. Although the etiology of PFP remains unclear, the most commonly accepted mechanism is related to excessive patellofemoral joint stress, which is believed to cause irritation and degradation of the retropatellar cartilage.[6] Although articular cartilage is aneural, it has been proposed that articular cartilage degeneration renders the subchondral bone susceptible to pressure variations that normally would be absorbed by healthy cartilage.[7]

In most cases, PFP is exacerbated with activities that require substantial quadriceps contraction.[2,8] This is supported by the fact that stair ambulation is reported as being one of the most challenging activities in this population. From a biomechanical standpoint, stair ascent and descent require greater knee flexion angles, increased knee extensor muscle moments, and substantially greater quadriceps force when compared with level walking.[9,10] Consequently, persons with PFP have been reported to employ compensatory strategies such as reducing peak knee extensor muscle moments and vasti muscle activity to minimize patellofemoral joint reaction forces and pain during this activity.[11,12]

A common intervention for PFP is bracing.[13–17] It has been reported that bracing decreases pain[13,18]; however, the mechanism by which bracing reduces symptoms is not clear. Although it is assumed that bracing improves patellar kinematics,[13,17] imaging studies have reported that bracing has little or no effect on patellar alignment or tracking.[19–21] It is possible, however, that patellar bracing decreases patellofemoral joint stress by seating the patella deeper within the trochlear groove.[21] As stress is defined as force per unit area, any increase in contact area between the patella and femur could result in the patellofemoral joint reaction forces (i.e., joint com-

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From the *Department of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA; the †Department of Radiology, Keck School of Medicine, University of Southern California, Los Angeles, CA; and the ‡Department of Orthopaedics, University of California San Diego, San Diego, CA.

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Reprints: Christopher M. Powers, PhD, PT, Department of Biokinesiology and Physical Therapy, University of Southern California, 1540 E. Alcazar St., CHP-155, Los Angeles, CA 90089-9006 (e-mail: powers@usc.edu).

pressive forces) being distributed over a greater surface area, thereby reducing patellofemoral joint stress.

Recent, evidence in support of this theory was provided by Powers et al,[22] who reported that patellar bracing was effective in reducing patellofemoral stress during level walking. The observed decrease in stress was the result of increased contact area, as the patellofemoral joint reaction forces also were increased following bracing. Whether or not the same result would be evident during an activity that is typically associated with the reproduction of PFP symptoms (i.e., stair ambulation) has not been explored.

Using a patient-specific image-based model of the patellofemoral joint, the purpose of this study was to test the hypothesis that individuals who respond favorably to bracing (as determined by an immediate reduction of PFP following application) would exhibit decreased patellofemoral joint stress during stair ambulation. Knowledge of the effect of bracing on patellofemoral joint kinetics during stair ambulation in subjects would provide additional information about the usefulness of bracing as a treatment intervention for improving function and reducing pain in this population.

METHODS

Subjects

Fifteen females between the ages of 18 and 43 years with a diagnosis of PFP participated in this study. The average age, height, and weight of these subjects was 29.9 ± 8.0 years, 163.8 ± 4.6 cm, and 58.0 ± 8.0 kg, respectively. Subjects were recruited from orthopedic clinics in the Los Angeles area and were screened by physical examination to rule out ligamentous instability, internal derangement, and patellar tendinitis. Subjects were admitted to this study if (1) pain originated from the patellofemoral joint articulation, (2) pain was readily reproducible with activities commonly associated with PFP (e.g., squatting, stair climbing, knee extension), and (3) pain was reduced following bracing. As the purpose of this study was to evaluate why bracing reduces symptoms, only those subjects who reported decreased pain with bracing were included (see pain criterion below). Subjects were excluded if they reported having previous knee surgery or a history of traumatic patellar dislocation.

On average, subjects in this study reported moderate levels of patellofemoral pain based on visual analogue scale assessment (see below). Of the 15 subjects enrolled, 5 had unilateral symptoms, while 10 had bilateral symptoms. In cases in which bilateral symptoms were reported, only the most painful side was evaluated.

Procedures

All subjects completed 2 phases of data collection. Phase 1 consisted of magnetic resonance imaging (MRI) to determine patellofemoral joint contact area, while phase 2 consisted of kinematic and kinetic analysis of stair ascent and stair descent. Data obtained from both data collection sessions were required as input variables into a biomechanical model to quantify patellofemoral joint stress. Prior to participation, all subjects were informed of the nature of the study and signed a consent form approved by the Institutional Review Board of the University of Southern California Health Sciences Campus.

Magnetic Resonance Imaging

All imaging was performed at the University of Southern California Imaging Sciences Center. Axial plane images of the patellofemoral joint were obtained with a 1.5T magnet (GE Medical Systems, Milwaukee, WI) using a fast spoiled gradient echo pulse sequence with fat suppression (TE 1.5, TR 8.2, flip angle 10°). The image field of view was 10 cm × 10 cm with a 256 × 256 matrix interpolated to 512 × 512, giving a pixel size of 0.20 mm × 0.20 mm. Using this pulse sequence, the patellar and femoral cartilage was observed to be bright (white), and any separation between the cartilage surfaces appeared as a dark line.[23]

Resistance to the extensor mechanism was accomplished using a custom-built nonferromagnetic loading apparatus that resembled a leg press machine (Captain Plastic, Seattle, WA). This device allowed subjects to perform unilateral knee extension in the supine position. Loading was achieved by pushing against a footplate that was connected (through a pulley system) to a moveable carriage containing concrete weights.

Subjects were positioned supine on the loading device, and straps were placed across the hip and shoulders to stabilize the trunk and pelvis. To improve the signal to noise ratio and image resolution, two 5-inch receive-only coils were placed on each side of the knee joint (with the patella centered between) and secured with tape. Starting with the knee fully extended, subjects were instructed to place the foot of the symptomatic side (or in the case of bilateral symptoms, the most painful side) on the foot plate, and the device was moved into the MRI bore. The carriage was then loaded to 25% body weight, and imaging commenced. Following imaging at 0°, the patient was removed from the MRI bore and repositioned on the loading device. MRI scans were obtained at 0°, 20°, 40°, and 60° of knee flexion (as measured by standard goniometer).

Images were obtained statically under braced (On-Track; Don Joy, Vista, CA) and nonbraced conditions. The brace was comprised of a 5-mm neoprene knee cuff with a patellar cutout. Self-adhesive Velcro patches placed directly over the patella were used to secure a 5-mm neoprene pull strap, which applied a constant medial pull on the patella (Fig. 1).

Prior to and immediately following the application of the brace, subjects were asked to rate their perceived pain (visual analogue scale) while performing an activity that reproduced their symptoms (i.e., unilateral squat or deep knee bend). The visual analogue scale consisted of a 10-cm line, the ends of which defined the minimum and maximum perceived pain. Following the pain-provoking activity, each subject placed a mark on the line to indicate the intensity of pain. The degree of pain was converted to a numerical value based on the distance (in centimeters) from the minimum anchor point to the mark on the line (0 = no pain; 10 = maximum pain). Application of the brace was deemed to be successful if at least a 50% reduction in symptoms was reported. Based on this pain criterion, a total of 16 subjects were screened to enroll the 15 subjects reported in this study.

The sequence of braced and nonbraced imaging was randomized for each subject. Total imaging time was 60 seconds at each knee flexion angle.

Gait Analysis

Kinematic and kinetic analysis of stair ascent and descent was performed at the Musculoskeletal Biomechanics Research Laboratory at the University of Southern California. Three-dimensional motion was obtained using a 6-camera motion analysis system (Vicon; Oxford Metrics, Oxford, England). Kinematic data were sampled at 60 Hz and recorded digitally on a 1-GHz personal computer. Reflective markers (25-mm spheres) placed at specific anatomic landmarks were used to determine sagittal plane kinematics of the lower extremity. Ground reaction forces were collected at a rate of 600 Hz using an AMTI force plate (model #OR6-6-1; Newton, MA).

A 2-step wooden staircase using standard rise and run dimensions (step height = 20.5 cm; tread = 27.5 cm) was positioned above the force platform, without contacting any portion of it, and 1 piece of floor tile was removed to allow access to the subfloor below the level of the platform. With this arrangement, the force platform became 1 of the 3 steps negotiated during stair ascent and descent.[11]

Subjects were appropriately attired to permit marker placement directly on the skin. Anthropometric measures (body mass, height, leg length, distance between the anterior superior iliac spines, knee width, and ankle width) were obtained from each subject for use in estimating joint centers and segment inertial properties. Reflective markers were then taped (bilaterally) to the following landmarks: anterior superior and posterior superior iliac spines, distal lateral thigh, lateral femoral epicondyle, lateral tibia, lateral malleolus, second metatarsal head, fifth metatarsal head, and posterior calcaneus.

A small cutout (1 cm × 1 cm) on the lateral side of the brace allowed the lateral femoral epicondyle marker to be placed directly on the skin during the braced trials. As the primary force acting on the patella with the On-Track brace was provided by the neoprene pull strap, it was unlikely that this cutout compromised the forces acting on the patella.

FIGURE 1. Current patellofemoral brace evaluated in the current study was the On-Track Patellar Tracking System. Reprinted with permission.[22]

Subjects were allowed several practice trials to accommodate to the stair apparatus. All participants were instructed to walk in a step over step fashion at a self-selected pace. To ensure that the foot of the painful limb made contact with the force plate, the step cycle was initiated with the painful side for ascending stairs and the nonpainful side for descending stairs.

As persons with PFP are sometimes hesitant to negotiate stairs, it was felt that attempting to control for walking speed between braced and nonbraced conditions would force subjects into an unnatural gait patterns. However, the average stance times between braced and nonbraced conditions were similar for both ascending stairs (950 vs. 936 ms, respectively; $P = 0.614$) and descending stairs (857 vs. 880 ms, respectively; $P = 0.429$), which suggests that bracing did not influence cadence.

Three trials of ascending stairs and descending stairs were obtained for each subject. Ascending and descending stair trials were repeated following the application of the brace. All kinematic and kinetic data were collected simultaneously. The order of stair trials (ascending versus descending) as well as the order of brace conditions (braced versus nonbraced) were randomized.

Data Analysis

Patellofemoral Joint Contact Area

Contact area was measured from the sequential axial plane images of the patellofemoral joint. Images were displayed for analysis using Scion Medical Imaging Software (Scion Corp., Frederick, MD). The section of the image containing the patella and surrounding portion of the femur was enlarged to 1.5× normal view to enhance visualization of the articular cartilage. Contact was defined as areas of patella and femur approximation in which no distinct separation could be found between the cartilage borders of the 2 joint surfaces. Since cartilage is relatively bright on fat-suppressed fast spoiled gradient echo images, the definition of contact area was operatively defined as white on white.[23]

The line of contact (curvilinear) between the patella and femur was measured and recorded using the electronic calipers feature within the Scion software. To obtain contact area for each slice, the length of each respective line of contact was multiplied by the 1-mm slice thickness. The areas of contact from each sequential image were summed to obtain the total patellofemoral joint contact area (reported in square millimeters). This method has been shown to be reliable and comparable to contact area measurements obtained using Fuji pressure-sensitive film in cadaver specimens.[23]

Magnetic resonance imaging procedures were repeated for each knee flexion angle. Contact area measurements were made twice by the same investigator and averaged for final analysis. A straight line fit between each 2 consecutive data points provided approximate patellofemoral joint contact area for each knee flexion angle from 0° to 60°. As the maximum knee flexion angle that could be accommodated in the MRI bore was 60°, the contact area at 60° also was used as the contact area at 90°. This decision was based on the data of Powers et al,[24] who reported that changes in contact area between 60° and 90° are minimal (20–36 mm^2).

Knee Joint Kinematics and Kinetics

Reflective marker coordinate and force data were stored in a motion file generated by the Vicon 370 software. Data processing software (Workstation v. 3.5; Oxford Metrics) was used to reconstruct the 3-dimensional motion data and to identify the gait cycle events and filter the raw coordinate data. A second data processing program (Plug-in-gait model, v. 1.7; Oxford Metrics) was used to compute segment kinematics and inertial properties for the foot, shank, and thigh. The principal moment of inertia of each segment was determined from the subject's total body weight, segment geometry, and anthropometric data. The net sagittal plane muscle moment at the knee was calculated from the inertial properties, segment kinematics, and force plate data using standard inverse dynamic equations.

All knee moment data were scaled to body mass and reported in units of Nm/kg. Only kinematic and kinetic data corresponding to the force plate step were used. Data obtained from the 3 trials were averaged for statistical analysis.

Patellofemoral Joint Kinetics

As described previously, patellofemoral joint reaction force and stress were calculated using a biomechanical model.[25,26] Input variables for the model algorithm included knee joint angle, knee extensor moment, and patellofemoral joint contact area.

The effective lever arm (L_{eff}) for the quadriceps was calculated using a nonlinear equation ($L_{eff} = 8.0e^{-5}x^3 - 0.013x^2 + 0.28x + 0.046$, where x = knee joint angle) fit to the data points generated by van Eijden et al ($R^2 = 0.98$).[27] Quadriceps force

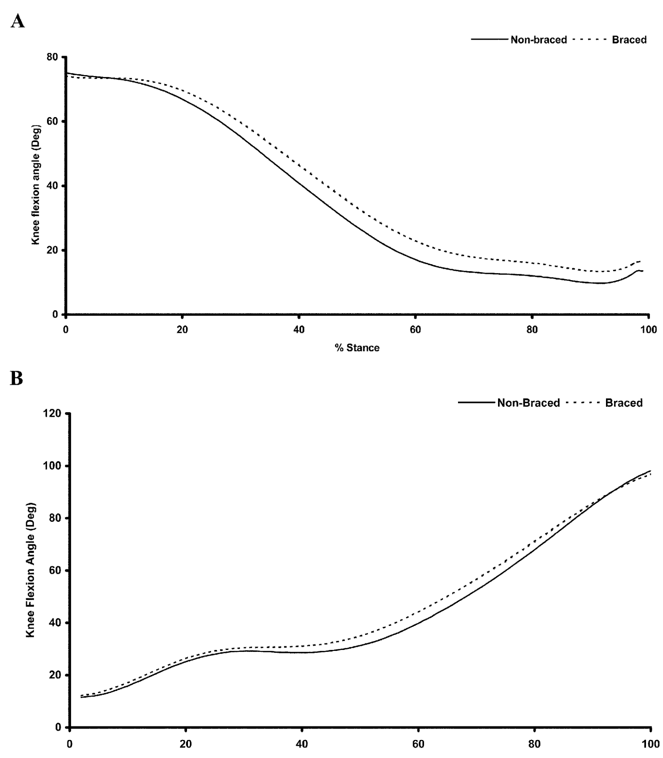

FIGURE 2. Knee angle plotted as a function of the stance phase for both nonbraced *(solid line)* and braced *(dashed line)* conditions during (A) stair ascent and (B) stair descent. There was no significant difference in knee kinematics between brace conditions.

(F_q) was then calculated by dividing the knee extensor muscle moment by the effective moment arm (Equation 1).

$$F_q = M_k/L_{eff} \quad (1)$$

Patellofemoral joint reaction force (JRF_{pf}) was calculated as the product of the quadriceps force and a constant k (Equation 2).

$$JRF_{pf} = k \cdot Fq \quad (2)$$

The constant k was determined for each knee flexion angle by using a nonlinear equation ($k = [-3.8e^{-5}x^2 + 1.5e^{-3}x + 0.462]/[-7.0e^{-7}x^3 + 1.6e^{-4}x^2 + 0.016x + 1]$) fit to the data points generated by van Eijden et al ($R^2 = 0.99$).[27]

Using the contact area obtained from the MRI at each of the 4 knee flexion angles (0°, 20°, 40°, and 60°), the final step of the model was to estimate patellofemoral joint stress. A straight line was fit between each 2 consecutive data points (i.e., 0° and 20°) to provide approximate patellofemoral joint contact area values for any knee flexion angle from 0° to 60°. For knee flexion angles greater than 60°, the straight line fit was extrapolated out to the maximum knee flexion angle measured. Patellofemoral joint stress (PFJS) was then calculated as the patellofemoral joint reaction force divided by the patellofemoral contact area (CA_{pf}) (Equation 3).

$$PFJS = JRF_{pf}/CA_{pf} \quad (3)$$

Statistical Analysis

Comparison of contact area between the braced and nonbraced conditions across flexion angles was made using a 2 × 4 (brace condition × knee flexion angle) analysis of variance with repeated measures. To determine if bracing influenced kinetic and kinematic variables across stair conditions, 2 × 2 (brace condition × stair condition) analyses of variance with repeated measures were performed. This analysis was repeated for each dependent variable (peak patellofemoral stress, peak patellofemoral joint reaction force, mean utilized contact area, peak knee extensor muscle moment, and knee flexion at the time of peak stress).

Significant main effects were reported if there were no significant interactions. If a significant interaction was identified, individual main effects were analyzed separately. All sta-

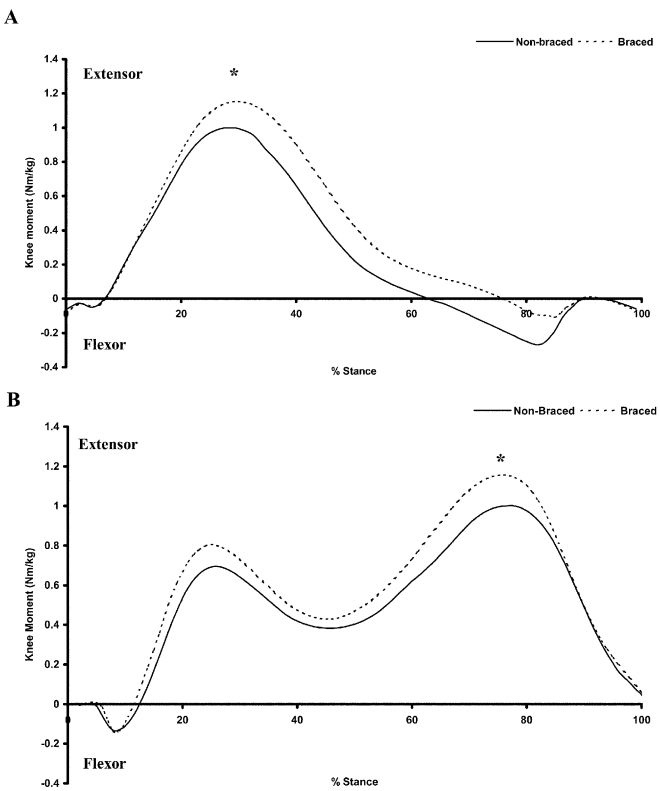

FIGURE 3. Net knee joint moment plotted as a function of the stance phase for both nonbraced *(solid line)* and braced *(dashed line)* conditions during (A) stair ascent and (B) stair descent. *Peak knee extensor moment was significantly greater in the braced condition when compared with the nonbraced condition.

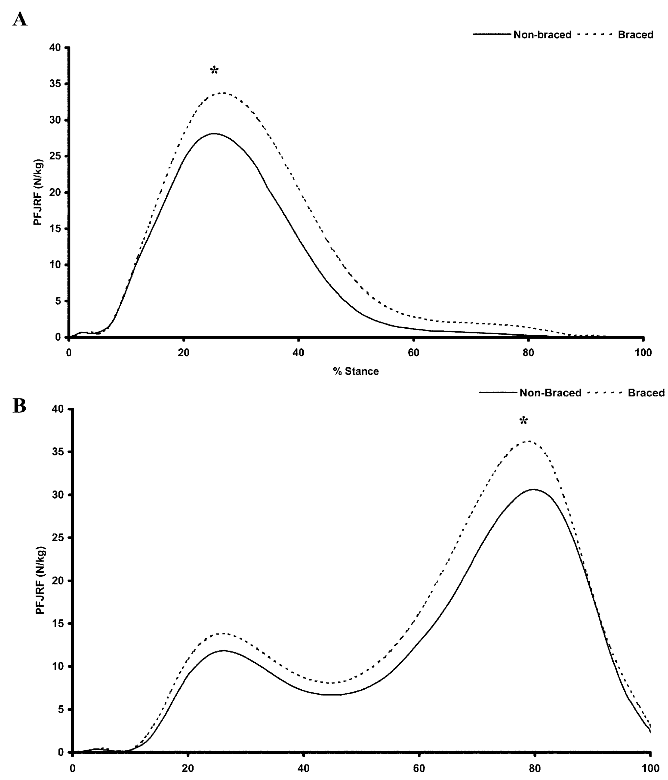

FIGURE 4. Patellofemoral joint reaction force (PFJRF) plotted as a function of the stance phase for both nonbraced *(solid line)* and braced *(dashed line)* conditions during (A) stair ascent and (B) stair descent. *PFJRF was significantly greater in the braced condition when compared with the nonbraced condition.

tistical analyses were performed using SPSS statistical software (SPSS, Chicago, IL) with a significance level of $P < 0.05$.

RESULTS

Pain Response

Based on the 10-point visual analogue scale, the average prebrace pain level was 4.8 ± 1.9, and the postbrace pain level was 2.1 ±1.8. This corresponded to a 56% reduction in pain.

Knee Kinematics

For both ascending stairs and descending stairs, there were no significant differences in knee kinematics between the braced and nonbraced conditions (Fig. 2A, B) (Table 1).

Net Knee Joint Moments

During stair ascent, the peak knee extensor muscle moment was significantly less in the nonbraced condition when compared with the braced condition (0.99 ± 0.18 vs. 1.15 ± 0.28 Nm/kg; $P = 0.02$; Fig. 3A). The same trend was observed during stair descent (1.08 ± 0.19 vs. 1.23 ± 0.24 Nm/kg; $P = 0.007$; Fig. 3B) (Table 1).

Patellofemoral Joint Reaction Force

During stair ascent, the peak patellofemoral joint reaction force was significantly less in the nonbraced condition when compared with the braced condition (28.6 ± 5.9 vs. 34.7 ± 9.7 N/kg; $P = 0.01$; Fig. 4A). During stair descent, the peak patellofemoral joint reaction force also was reduced in the nonbraced condition compared with the braced condition (31.4 ± 6.2 vs. 37.0 ± 11.2 N/kg; $P = 0.01$; Fig. 4B) (Table 1).

Patellofemoral Joint Contact Area

When compared with the nonbraced condition, application of the patellar brace resulted in significant increases in contact area at 0° (103.9 vs. 140.6 mm^2; $P = 0.012$), 20° (160.5 ± vs. 259 ± mm^2; $P < 0.001$), 40° (323.5 vs. 396.1 mm^2; $P <$ 0.001), and 60° (398.9 vs. 450.1 mm^2; $P < 0.001$).

During stair ascent, the mean utilized contact area was significantly less in the nonbraced condition compared with the braced condition (254 ± 35.6 vs. 342.4 ± 60.7 mm^2; $P <$ 0.001; Fig. 5A). Similarly, during stair descent, the mean utilized contact area was significantly less in the nonbraced condition when compared with the braced condition (278.6 ± 43.5 vs. 361.3 ± 67.3 mm^2; $P < 0.001$; Fig. 5B) (Table 1).

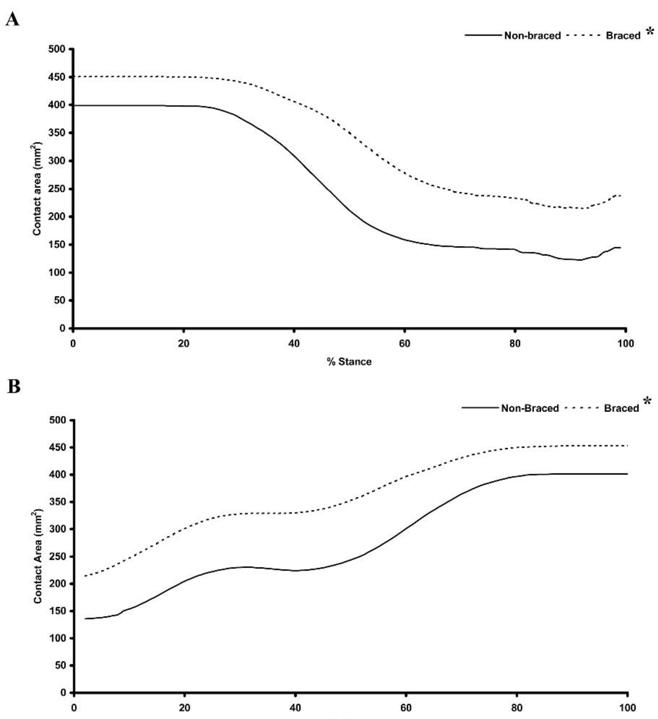

FIGURE 5. Used patellofemoral joint (PFJ) contact area plotted as a function of the gait stance phase for both nonbraced *(solid line)* and braced *(dashed line)* conditions during (A) stair ascent and (B) stair descent. *Used PFJ contact area was significantly greater in the braced condition when compared with the nonbraced condition.

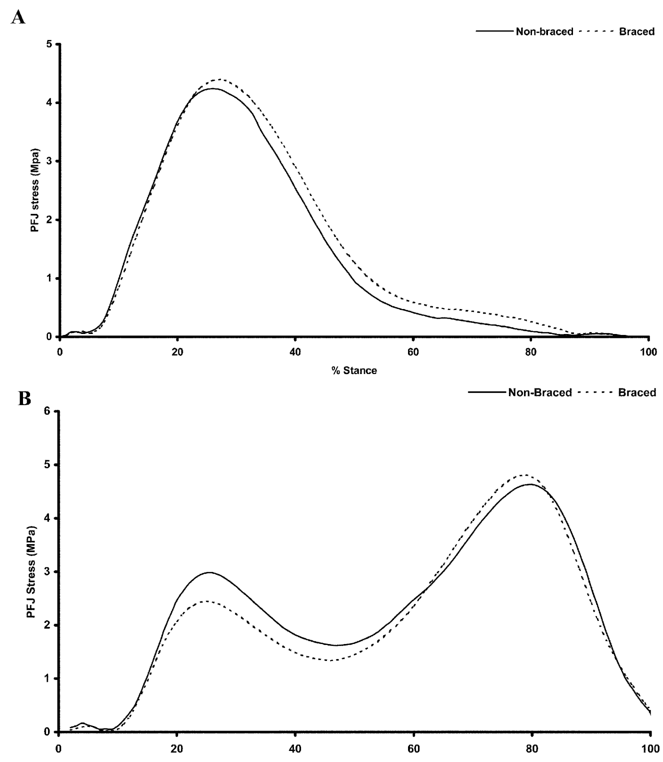

FIGURE 6. Patellofemoral joint (PFJ) stress plotted as a function of the stance phase for both nonbraced *(solid line)* and braced *(dashed line)* conditions during (A) stair ascent and (B) stair descent. No significant differences were found in peak patellofemoral stress between nonbraced and braced conditions for either ascending or descending stairs.

Patellofemoral Joint Stress

For ascending stairs, there was no significant difference in peak patellofemoral joint stress between the braced and nonbraced conditions (Fig. 6A). Similarly, there was no significant difference in peak patellofemoral joint stress between the braced and nonbraced conditions when descending stairs (Fig. 6B).

DISCUSSION

The purpose of this study was to test the premise that individuals who respond favorably to bracing would exhibit decreased patellofemoral joint stress during stair ambulation. Our hypothesis was not supported, however, as no differences in peak stress were observed during either stair ascent or descent. This finding is somewhat surprising considering that on the average, subjects reported a 56% decrease in pain following the application of the brace.

The lack of a difference in peak stress between braced and nonbraced conditions can be explained by looking at the components of the stress equation, namely joint reaction force and contact area. When averaged across all knee flexion angles, contact area following bracing increased 33%. In addition, used contact area (which represents contact area as a function of knee flexion angle during gait) increased 34% and

TABLE 1. Descriptive Statistics of all Variables

	Mean	SD	Mean Difference	95% Confidence Interval of Difference		P Value
				Lower	Upper	
Ascend stairs						
Knee flexion angle at time of peak stress (°)						
Nonbraced	61.09	4.42	0.82	−0.22	1.67	0.06
Braced	61.91	4.30				
Peak knee extensor moment (Nm/kg)						
Nonbraced	0.99	0.18	0.16	0.04	0.29	0.02
Braced	1.15	0.28				
Peak PFJ reaction force (N/kg)						
Nonbraced	28.58	5.86	6.16	1.65	10.66	0.01
Braced	34.74	9.68				
Average utilized PFJ contact area (mm^2)						
Nonbraced	254.69	35.59	87.69	63.58	111.80	<0.001
Braced	342.38	60.74				
Peak PFJ stress (MPa)						
Nonbraced	4.27	1.14	0.20	−0.59	0.99	0.60
Braced	4.48	1.21				
Descend stairs						
Knee flexion angle at time of peak stress (°)						
Nonbraced	62.68	14.05	1.20	−1.26	3.67	0.31
Braced	63.88	15.17				
Peak knee extensor moment (Nm/kg)						
Nonbraced	1.08	0.19	0.15	0.05	0.25	0.01
Braced	1.23	0.24				
Peak PFJ reaction force (N/kg)						
Nonbraced	31.40	6.20	5.60	1.73	9.46	0.01
Braced	37.00	11.15				
Average utilized PFJ contact area (mm^2)						
Nonbraced	278.63	43.51	82.65	60.23	105.07	<0.001
Braced	361.28	67.28				
Peak PFJ stress (MPa)						
Nonbraced	5.06	1.50	0.51	−0.58	0.68	0.86
Braced	5.11	1.65				

29% for ascending and descending stairs, respectively. However, patellofemoral joint reaction forces also increased during the brace trials (20% and 18% for ascending and descending stairs, respectively), negating any stress reduction. The increase in the joint reaction force was the result of an increase in the knee extensor muscle moment, as the knee kinematics were similar between brace trials.

The finding of lower knee extensor muscle moments in the nonbraced trials compared with the braced trials suggests that subjects may have been compensating to reduce the forces (and therefore stress) acting across the patellofemoral joint. Such a compensation is suggestive of quadriceps avoidance and has been reported previously in this population.[11] It is conceivable that during the nonbraced trials, the PFP subjects adopted a particular gait pattern that lowered the joint reaction forces, thereby keeping stress at a tolerable level.

The fact that bracing resulted in an amount of stress comparable to that of the nonbraced condition appears to be clinically relevant, as subjects were able to generate greater knee extensor muscle moments and tolerate greater patellofemoral joint reaction forces. As quadriceps weakness is a common clinical finding in this population, a quadriceps avoidance gait pattern may lead to disuse atrophy and further weakness. This appeared to be reversed following bracing, which could be interpreted as a positive response.

The greatest change in contact area following bracing occurred at 20° (61%). Although statistically significant, the increases at 40° and 60° were substantially smaller (22% and 12%, respectively). As most of the stance phase of stair ascent and descent requires knee flexion angles greater than 20°, any reduction in stress as a result of increased contact area would not be as dramatic. Given as such, bracing would appear to have its maximum effect in reducing stress with activities that require smaller knee flexion angles, which may explain why a previous investigation reported decreases in patellofemoral stress following bracing during level walking.[22]

As elevated patellofemoral stress is believed to be related to PFP, the fact that the substantial decrease in pain was not accompanied by a similar reduction in stress was an unexpected finding. However, it should be noted that stress was not quantified during the provocative maneuver used to reproduce symptoms, and therefore, a cause and effect relationship between stress and pain cannot be made. In addition, the subjective nature of pain reporting makes it is difficult to tease out the psychologic aspects associated with wearing a brace (i.e., placebo effect that could influence the reporting of pain). Alternatively, previous work in our laboratory has shown that bracing increases not only lateral facet contact area but also medial facet contact area.[28] This suggests that bracing also has to potential to unweight pain-sensitive areas. Further research is necessary to test this hypothesis.

A limitation of this study was the fact that only those individuals who responded favorably to bracing were included. Therefore, care must be taken in extrapolating the results of this study to all persons with PFP. However, the fact that 94% of persons with PFP who were screened for this study responded favorably (15 out of 16) suggests that a positive response with this particular brace is more the norm than the exception. Whether or not similar biomechanical findings would evident in those who do not respond to bracing remains to be seen. Also, contact areas obtained in this study were obtained under static as opposed to dynamic conditions. Current imaging technology does not permit dynamic high-resolution assessment of articular cartilage, so it is not possible to determine the potential influence of loading condition on this parameter.

CONCLUSIONS

Despite substantial decreases in pain, bracing did not reduce peak stress during stair ascent and descent. This finding can be explained by the fact that despite improvements in contact area, bracing resulted in greater knee extensor moments and joint reaction forces. This increase in quadriceps utilization and tolerance of joint forces would appear to be a beneficial consequence of bracing.

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