Effects of Patellar Taping on Brain Activity During Knee Joint Proprioception Tests Using Functional Magnetic Resonance Imaging

Michael J. Callaghan, Shane McKie, Paul Richardson, Jacqueline A. Oldham

Background. Patellar taping is a common treatment modality for physical therapists managing patellofemoral pain. However, the mechanisms of action remain unclear, with much debate as to whether its efficacy is due to a change in patellar alignment or an alteration in sensory input.

Objective. The purpose of this study was to investigate the sensory input hypothesis using functional magnetic resonance imaging when taping was applied to the knee joint during a proprioception task.

Design. This was an observational study with patellar taping intervention.

Methods. Eight male volunteers who were healthy and right-leg dominant participated in a motor block design study. Each participant performed 2 right knee extension repetitive movement tasks: one simple and one proprioceptive. These tasks were performed with and without patellar taping and were auditorally paced for 400 seconds at 72 beats/min (1.2 Hz).

Results. The proprioception task without patellar taping caused a positive blood oxygenation level–dependant (BOLD) response bilaterally in the medial supplementary motor area, the cingulate motor area, the basal ganglion, and the thalamus and medial primary sensory motor cortex. For the proprioception task with patellar taping, there was a decreased BOLD response in these regions. In the lateral primary sensory cortex, there was a negative BOLD response with less activity for the proprioception task with taping.

Limitations. This study may have been limited by the small sample size, a possible learning effect due to a nonrandom order of tasks, and use of a single-joint knee extension task.

Conclusions. This study demonstrated that patellar taping modulates brain activity in several areas of the brain during a proprioception knee movement task.

M.J. Callaghan, PhD, MPhil, MCSP, Arthritis Research UK Epidemiology Unit, School of Translational Medicine, University of Manchester, 2nd Floor, Stopford Building, Oxford Road, Manchester M13 9PT, United Kingdom. Address all correspondence to Dr Callaghan at: michael.callaghan@manchester.ac.uk.

S. McKie, PhD, Neuroscience and Psychiatry Unit, University of Manchester.

P. Richardson, PhD, Brain Behaviour and Cognition Group, Sheffield Hallam University, Sheffield, United Kingdom.

J.A. Oldham, PhD, Centre for Rehabilitation Science, University of Manchester.

[Callaghan MJ, McKie S, Richardson P, Oldham JA. Effects of patellar taping on brain activity during knee joint proprioception tests using functional magnetic resonance imaging. *Phys Ther.* 2012;92:821–830.]

Published Ahead of Print: January 26, 2012
Accepted: January 22, 2012
Submitted: July 4, 2011

Patellar taping is a simple and cost-effective technique introduced in the mid 1980s to alleviate the symptoms of patellofemoral pain syndrome (PFPS) or anterior knee pain.[1] Although realignment of the patella was one of the proposed mechanisms for the success of this technique, it has been shown from radiographic,[2] computerized axial tomography,[3] structural magnetic resonance imaging (MRI),[4] and kinematic[5] studies that the tape does not significantly alter patellar mediolateral alignment. It has been demonstrated that patellar taping can improve proprioception of the knee in people who are healthy[6] and in patients with PFPS.[7] These results suggest that there may be other, more subtle sensory mechanisms at work through skin, tendon, and muscle stimulation that may account for the improvement of a joint position sense task and for the success of patellar taping. All proprioception studies so far have measured variables along the efferent and afferent pathways or have assessed the final outcome of skeletal muscle activation and joint movement.[8] *Proprioception* was operationally defined in this study as the ability to reproduce a target angle of 20 degrees of knee extension using the active angle reproduction method for joint position sense.

Functional magnetic resonance imaging (fMRI) has emerged as a promising technique for the detection and assessment of cerebral physiology and pathophysiology and the regional mapping of human cognitive functions such as motor and memory.[9] It provides an indirect measure of neuronal activity, as it is based on secondary metabolic and hemodynamic events that follow neuronal activity rather than the electrical brain activity itself.[10] The most common fMRI technique uses blood oxygenation level–dependent (BOLD) contrast, which reflects the loss of oxygen from hemoglobin causing its iron to become paramagnetic. When a task is performed, there is consequent neuronal activity and an increase in oxygen usage. These changes are followed within a few seconds by a larger fractional increase in blood flow and an increase in blood volume, resulting in a decrease in the amount of deoxygenated blood present. It is this change that the BOLD contrast technique detects. Several research groups have investigated the amount of brain activity involved during movement of the knee.[11–15] These studies showed that knee movement resulted in significant activation of the primary motor cortex (M1); the supplementary motor area (SMA), the primary sensorimotor cortex (SM1); the cingulate motor area (CMA); the pre-motor cortex (pre-SMA); the primary and secondary sensory cortices (S1 and S2); the basal ganglia and its major component, the globus pallidus; the cerebellum; and the thalamus. These regions of interest are concerned with movement tasks, the process of proprioception, sensation, the decision making needed for a proprioception task, planning of complex coordination tasks, and the coordination of the unconscious aspects of proprioception.

Although the application of a knee sleeve, brace, or tape is a common therapeutic technique to reduce pain and improve function in a variety of patellar problems, their mechanism has been debated, with opinion moving toward a sensory stimulation and proprioception explanation.[6,16,17] To date, only one study has examined the brain response after their application. Thijs et al[15] found that a tight elasticated knee brace and a less tight knee sleeve both increased brain activity in the SM1 in contrast to a control condition. Although they concluded that both the brace and sleeve increased brain activation during knee movement as a result of increased proprioceptive input, their participants performed each task from 0 to 90 degrees of knee flexion, which was not a proprioception task.

Currently, no studies have investigated the effects of commonly used patellar taping techniques during knee joint proprioception tasks on higher brain centers in healthy or injured knees. The aim of this study was to examine, using a 2 × 2 factorial design, brain activity during a knee joint proprioception task and monitor any changes occurring when patellar tape was applied. The hypothesis was that brain activity in the specified regions of interest, especially in the sensory areas, would be altered by the application of patellar tape during a knee joint proprioception task, specifically joint position sense.

Method

Participants

A convenience sample of 8 male volunteers who were healthy and from health care professions was recruited. Their mean age was 29.4 years (SD=6.5), mean body mass

Available With This Article at ptjournal.apta.org

- eFigure: Setup in the Scanner
- eTable 1: Effect of Knee Movement Across All 4 Conditions
- eTable 2: Effect of Knee Movement Under Tape Versus No Tape
- eTable 3: Effect of Knee Movement Doing Simple Task Versus Proprioception Task

index was 32.9 kg/m^2 (SD=8.8), mean Waterloo Footedness Questionnaire score was 9 (SD=5.2), and mean Baecke Questionnaire score was 8.9 (SD=1.4). The scores for the Waterloo Footedness Questionnaire revealed right-leg dominance for all participants, and the Baecke Questionnaire revealed homogeneous habitual physical activity. These data were comparable to those of Kapreli et al.[12]

All participants gave their written informed consent. Data collection took place in a university research facility over a 12-month period. Participants were scanned at the same time of day to remove circadian effects. This was a preliminary study, and there were no previous data on which to base a power calculation. The sample size was deemed sufficient for this type of fMRI study design, as large effect sizes usually are seen with fMRI.

Exclusion Criteria

Volunteers were excluded from the study if they had a history of neurological or cardiovascular disease or a history of serious musculoskeletal injury in either lower limb. Further exclusions related to MRI contraindications included cochlear implants or any metal objects in the body and use of cardiac or neural pacemakers. Other exclusions specifically for fMRI were caffeine intake several hours before the scanning session commenced and the use of antidepressants, anticoagulant medications, or psychoactive drugs.

Inclusion Criteria

Volunteers were included in the study if they were right-leg dominant, as determined by the Waterloo Footedness Questionnaire–Revised[18]; were not participating in special sports or physical activity, as determined by the Baecke Questionnaire[19]; and were symptom free with no abnormalities at the knee joint or lower limb, as assessed clinically by a specialist in musculoskeletal examination.

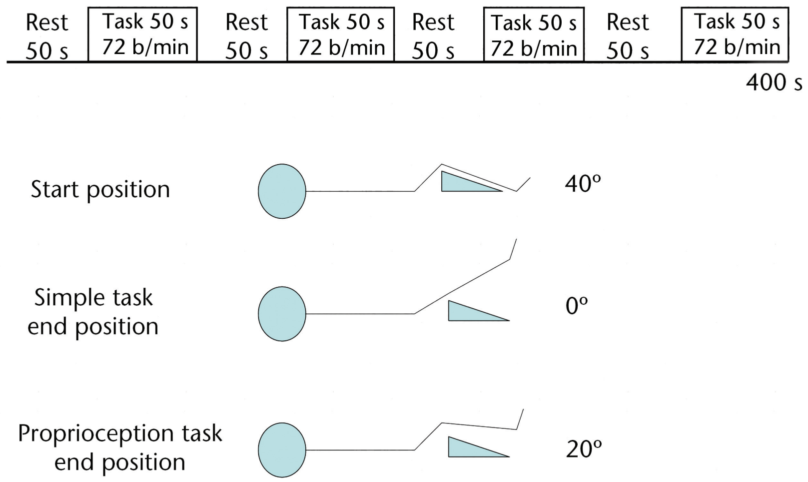

Figure 1.
Diagram of the tasks. Task: 50 seconds at 72 beats/min=60 repetitions. Total of 240 repetitions=total of 80 images. Total task time=1,600 seconds (26.6 minutes).

Participant Positioning

The participants wore shorts and lay in a supine position in the scanner. A wooden block supported the thigh and knee at an angle of 40 degrees of knee flexion and 45 degrees of hip flexion. Head movement was restricted using foam pad Velcro straps (Velcro USA Inc, Manchester, New Hampshire) and a bite bar. A strap was placed over the hips to further limit head motion as a consequence of lower-limb movement. To ensure minimum ankle, foot, and toe movements during the test, these joints were placed in a neutral position and held by a plastic molded cast[12] (eFigure, available at ptjournal.apta.org).

Experimental Design

Each scanning session consisted of 4 separate fMRI scans, namely: a simple task and a proprioception task performed with and without patellar tape. A block design was used with a rest period in which the participants lay awake quietly in a resting state (Fig. 1). Each block was 50 seconds in duration and was cued by a visual command on a screen (green=rest, red=move). Participants were instructed before each fMRI scan to extend their knee from the baseline angle of 40 degrees of flexion to a target angle of either 20 degrees of flexion (the proprioception task) or 0 degrees (full knee extension [ie, the simple task]) and without delay return it to the baseline angle of 40 degrees. A metronome, which could be heard using MRI customized headphones, paced the movements in all conditions at a constant 72 beats/min (1.2 Hz), which constituted 60 knee movements per 50-second block. For the proprioception task, the target angle of 20 degrees was determined with a universal goniometer aligned from the greater trochanter to the lateral malleolus through the lateral knee joint line. Prior to data collection, the participants practiced the knee extension maneuver. Accuracy was achieved after approximately 10 repetitions with feedback provided by the investigator as to their accuracy attaining the target angle of 20 degrees.

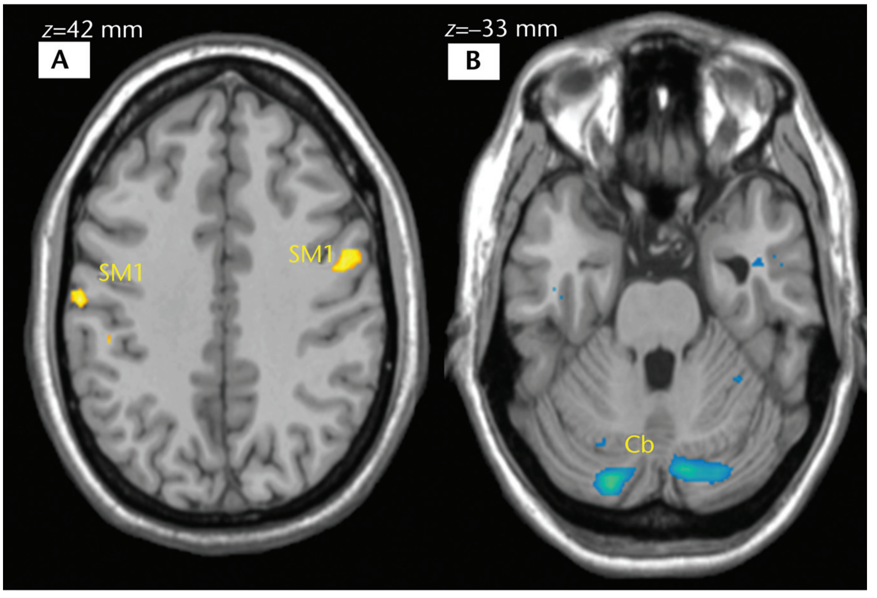

Figure 2.
The effects of taping on both types of knee movement tasks: (A) primary sensorimotor cortex (SM1)=bilaterally tape > no tape; (B) cerebellum (Cb) no tape > tape. Yellow=areas of high statistically significant levels of activity in contrast to the other conditions, light blue=areas of negative activity in contrast to other conditions, dark blue=areas of more negative activity in contrast to other conditions.

Patellar Taping

Patellar tape was applied using a previously published method.[6,7] In brief, the participants lay with a relaxed, fully extended knee (0° of flexion), and one strip of tape was applied without tension across the center of the patella. The center of the tape was as near as possible to the center of the patella, with its medial and lateral edges aligned with the medial and lateral joint lines. The tape was not pulled in either a medial or lateral direction because the participants were asymptomatic with no evidence of patellar malalignment. Because of anthropometric differences among the participants, the length of tape may have led to some smaller patients getting proportionally greater amounts of tape than others. Thus, the length of tape was calculated with a tape measure to be 50% of the total circumference of the individual's knee.

Imaging Acquisition

Full-brain fMRI images were obtained using an echo planar imaging sequence, sensitive to the BOLD contrast, on a Philips 1.5-Tesla Intera scanner (Philips, Best, the Netherlands), (repetition time/echo time=5,000/40, in-plane resolution 3 mm × 3 mm, slice thickness=3 mm, slices=40). Each task lasted for 400 seconds so that 80 images were acquired per scan.

Functional Magnetic Imaging Analysis

Statistical analysis was performed using SPM5 (Department of Cognitive Neurology, Wellcome Trust Centre for Neuroimaging, London, United Kingdom).[20] This is standard software used for this type of analysis. For each participant, the entire image data set was spatially realigned to the first image of each fMRI scan using rigid-body registration.[21] The realigned images then were spatially normalized into a reference system using a representative brain (Montreal Neurological Institute, Montreal, Quebec, Canada) as a template. Normalization was done by an affine and nonlinear transformation, mapping the mean functional scan to the template. Finally, the images were smoothed with a Gaussian kernel of 6 mm full width at half maximum for purposes of participant and group analysis.[22]

First-level statistical data analysis consisted of modeling the different conditions using a boxcar function convolved with a delayed hemodynamic response function in the context of the general linear model.[23] Global changes of the BOLD signal were adjusted by scaling, and a 0.004-Hz high-pass filter removed any low-frequency signal drifts. In addition, realignment parameters (3 rotation and 3 translation parameters) were included in the design matrix as covariates of no interest to correct for confounding effects induced by head movement.[24] Statistical parametric maps then were generated, testing for the effects of interest by applying appropriate linear contrast to the parameter estimates of each condition. A separate group analysis was performed using a random effect analysis[25] to identify voxels showing a significant difference in activation between movement conditions and rest.

Group Analysis

A 2 × 2 repeated-measures factorial analysis of variance was used to detect significant main effects and interactions. Four contrasts were investigated: the main effect of moving the knee, the main effect of the simple task versus the proprioception task, the main effect of tape versus no tape, and the interaction between the tape and task conditions (tape [proprioception task-simple task]−no tape [proprioception task-simple task]). Activation was measured in several regions of interest based on the knee fMRI studies mentioned in the introduction,[11–14] namely: the M1; the SMA proper; the SM1; the CMA; the pre-SMA; the S1 and S2; the basal ganglion and its major component, the globus pallidus; the cerebellum; and the thalamus. For all comparisons listed above, the threshold was set at $P(FWE)<.05$ small volume corrected for multiple comparisons for activation height within the *a priori* regions of interest. Only those with a cluster size greater than 5 are reported.

Role of the Funding Source

Funding for this study was provided by a Wellcome Trust Clinical Research Facility Translational Imaging Unit grant and by a National Institute for Health Research (NIHR) postdoctoral award to Dr Callaghan. The funding sources had no role in the study's data analysis or dissemination of results.

Results

There were no adverse events from the taping or scanning procedures, and no scans had to be excluded from analysis due to excessive head movement.

Main Effects of Knee Movement

Both simple and proprioceptive knee movement tasks activated large areas of the brain with a positive BOLD response, including the bilateral SMA proper, S2, CMA, cerebellum, ventral tegmental area (VTA)/brain stem, and thalamus (eTab. 1, available at ptjournal.apta.org). A negative BOLD response was observed bilaterally in S1, SM1, and SMA.

Main Effects of Tape

There was an increased BOLD response across both tasks bilaterally in the SM1 when using tape compared with no tape. This finding is represented by the yellow areas, indicating highly significant levels of activity in contrast to the no-tape condition, in Figures 2A and 3A. There was decreased activity in the cerebellum bilaterally when using tape compared with no tape, which is shown as light blue and dark blue areas in Figures 2B and 3B (eTab. 2, available at ptjournal.apta.org).

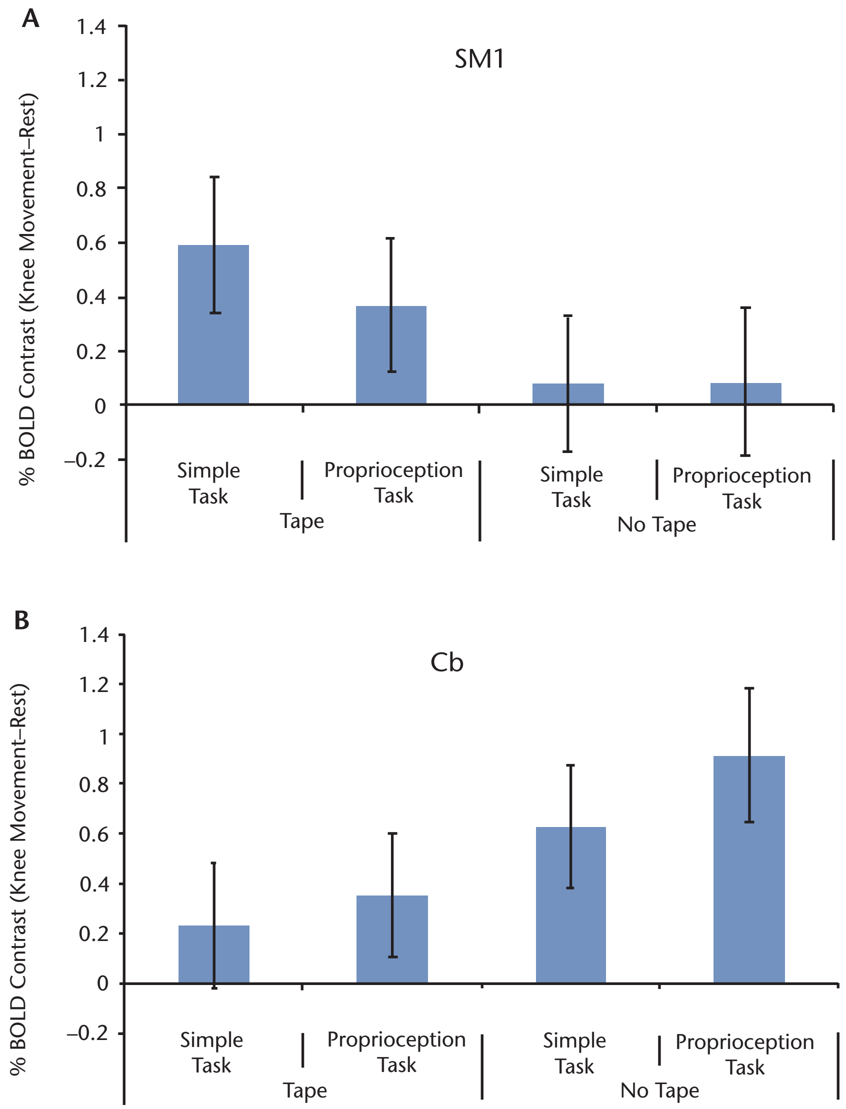

Figure 3.
Histogram showing percentage of blood oxygenation–level dependent (BOLD) contrast responses in the: (A) primary sensorimotor cortex (SM1); (B) cerebellum (Cb).

Main Effects of Tasks

There was an increased BOLD response when comparing the simple task with the more complex proprioception task in the right SMA proper, cerebellum, and VTA of the brain stem and bilaterally in the precentral gyrus. There was decreased activity, driven by a negative BOLD response, bilaterally in the SMA and pre-SMA (middle and superior gyri) when comparing the proprioception task with the simple task (eTab. 3, available at ptjournal.apta.org).

Main Interaction Effects (Task Versus Tape)

There was a positive interaction between task and tape, as indicated

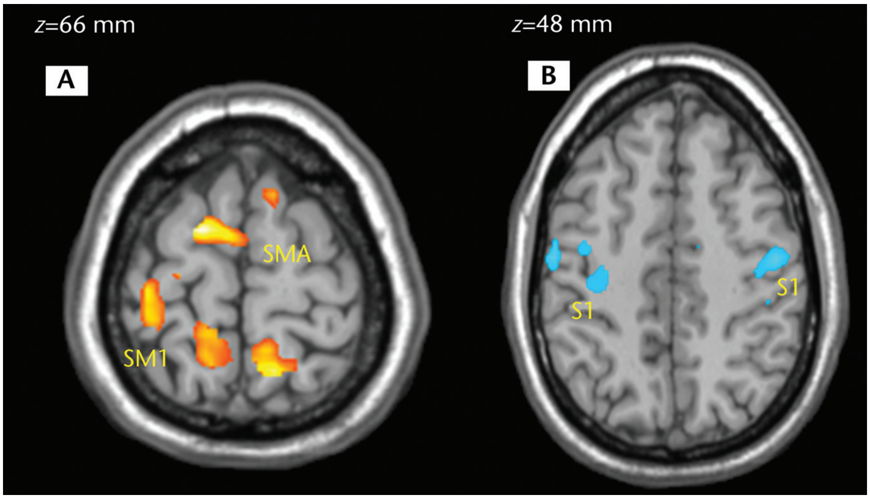

Figure 4.
The interaction effect of tasks and tape: (A) supplementary motor area (SMA) and primary sensorimotor cortex (SM1) for tape (proprioception task−simple task) > no tape (proprioception task−simple task); (B) primary sensory cortex (S1) for no tape (proprioception task−simple task) > tape (proprioception task−simple task). Yellow=areas of high statistically significant levels of activity in contrast to other conditions, red=areas of less statistically significant levels of activity in contrast to other conditions, light blue=areas of negative activity in contrast to other conditions, dark blue=areas of lower negative activity in contrast to other conditions.

by the red and yellow areas in Figure 4A and as detailed in the top half of the Table. This interaction is seen as a positive BOLD response in the medial SM1 and SMA at the superior frontal and precentral gyri, as well as in the CMA, basal ganglion, and thalamus. This response is illustrated by the histogram in Figure 5A, which shows the BOLD response compared with rest in all task and tape conditions for the medial SM1 and SMA.

The lateral SMA and lateral SM1 had a negative BOLD response and a negative interaction between task and tape, which are represented by the blue areas in Figure 4B and are detailed in the bottom half of the Table. In the lateral S1, there also was a negative BOLD response compared with rest in the proprioception task with tape and the simple task without tape. This response is shown in the histogram in Figure 5B.

Discussion

Patellar taping has been adopted worldwide for the treatment of people with PFPS. Although the effect of taping on knee joint proprioception has been investigated previously using a joint position sense task,[6,7] this is the first study to analyze the effects of this commonly used intervention with fMRI.

This study has shown that there is altered brain response when a simple strip of tape is applied to the right patella of individuals who are healthy during a proprioception task compared with a simple task, but the direction of the responses does not always mean that there is an increase in brain activity. The tape *increased* BOLD response in some areas (eg, SM1, S1), whereas in other areas (eg, CMA, cerebellum), the BOLD response was *decreased* by the application of tape. These findings support the theory that taping may be an efficacious therapy due to subtle mechanisms affecting the brain, not just because it gives mechanical support to the patella or alters lower-limb biomechanics.[26]

Knee Movement Compared With Rest

When knee movement was compared with rest, both simple and proprioception tasks activated large areas of both cortices, including the SM1, pre-SMA, SMA proper, and cerebellum. These areas of brain activity are similar to those previously described,[11–14] with predominant involvement of the SMA proper and the SM1. The current study also noted bilateral hemisphere activation during the tasks and with the interaction between tape and the proprioception task. It has been noted previously by Luft et al[11] that bilateral activation seems to be a feature of lower-extremity movement regardless of the joint and its complexity.

This study also demonstrated a negative BOLD response in the bilateral S1, SMA (superior frontal and precentral gyri), and SM1. Why knee movement should cause *decreased* activity in some areas of the brain is difficult to explain. It is possible that knee movement was modulated by some form of interaction between the lower-limb and upper-limb representations due to small movements in the wrist and hand and the foot and ankle. Newton et al[14] noted this feature in the SM1 (precentral gyrus), which is Brodmann area 4/6, known as the "hand knob" area for hand motor function.[27] We followed Kapreli and colleagues'[12] method in which foot and ankle movements were controlled by a plastic splint (eFigure), but participants' hand and wrist movements in their study and in the present study were neither controlled nor monitored. It is possible, although still speculative, that inadvertent upper-limb movement during the scan may have modulated the BOLD response for knee extension.

Table.
Interaction Effect of Task and Tape on Knee Movement (No Tape [Proprioception Task−Simple Task] > Tape [Proprioception Task−Simple Task]): Standard Parametric Mapping-Montreal Neurological Institute Coordinates and Brodmann Areas of Peak Activation in the Regions of Interest at *P(FWE)*<.05 Small Volume Corrected For Multiple Comparisons[a]

Regions of Interest	Brodmann Areas	Side	Brain Area	*t*	*z* Score	x	y	z
Tape (proprioception task−simple task) > no tape (proprioception task−simple task)								
Postcentral gyrus	3/4	L	SM1	4.16	3.64	−9	−48	69
		R	SM1	4.06	3.57	12	−42	69
Superior frontal gyrus	6	L	SMA	3.65**	3.28	−21	6	69
		R	SMA	4.95**	4.16	15	0	69
Precentral gyrus	4/6	L	SM1	3.49**	3.16	−12	−15	75
		R	SM1	3.83**	3.41	36	−21	69
No tape (proprioception task−simple task) > tape (proprioception task−simple task)								
Precentral gyrus	6	L	SMA	4.59	3.93	−15	−6	57
Cingulate gyrus	24		CMA	4.16	3.64	3	−9	45
Lentiform nucleus	Putamen	L	BG/T	3.72	3.33	−24	3	−9
Precentral gyrus/ postcentral gyrus	6	L	S1	3.22**	2.95*	−42	−9	45
		R	S1	4.15**	3.63	54	−12	45

[a] Talairach regions=refers to the standard atlas of brain regions. L=left, R=right, SM1=primary sensorimotor cortex, SMA=supplementary motor area, CMA=cingulate motor area, BG/T=basal ganglion/thalamus, S1=primary sensory cortex. x, y, and z=3-dimensional x, y, and z coordinates. *Value does not survive small volume correction but is bilateral; **negative blood oxygen level–dependent (BOLD) response is driving the interaction.

Simple Task Compared With Proprioception Task

Comparing the 2 tasks, the increased activity in the right SMA proper and S1 and bilaterally in the precentral gyrus, cerebellum, and VTA of the brain stem during the proprioception task reflected the greater demand on coordination and decision making during this task. An increase in BOLD response in the SMA and pre-SMA during the simple task was due to the participants moving their knees through the greater range of motion of 40 degrees compared with 20 degrees in the proprioception task (eTab. 2). We were not able to measure the exact knee angle achieved during the proprioception task due to the technical problems of working within the scanner room and reading the angle accurately from a handheld goniometer. However, the fact that the participants were making conscious decisions to accurately achieve the 20-degree knee angle ensured a comparison between a simple task and a more complex proprioception task.

Patellar Tape Compared With No Tape

When patellar tape was applied during either of the 2 tasks, there was decreased activity in the anterior cingulate and the cerebellum, which are the regions of interest concerned with proprioception, the decision making and planning of complex, coordinated tasks, and the coordination of the unconscious aspects of proprioception (Fig. 2B). The histogram (Fig. 3B) shows that although both conditions demonstrated an increase in BOLD response, the taping condition had a lower percentage of increase and was closer to zero compared with the no-tape condition. This finding indicates a relative decrease in activity with the tape on, which could be interpreted as participants perceiving the task to be easier to perform with the tape and, as a result, the activity of the cerebellum and anterior cingulate was less because these areas did not have to work as hard. The increase in activity in the SM1 when the tape was applied was greater than without tape, as might be expected from the sensory input from tape (Fig. 2A and Fig. 3A).

Interaction of Task and Tape Conditions

The analysis of interaction between the simple or proprioception tasks, with or without tape, revealed a mixed pattern of BOLD responses and brain activity. In the medial SMA, CMA, basal ganglion, and thalamus, there was an increase in activity using all combinations of tasks and conditions. The highest activity in the simple task with tape probably reflected the greater range of knee movement (40°) combined with the sensory input from the tape (Fig. 4A). The lesser activity during the proprioception task with tape was likely due to the task being perceived as being easier with the tape, thus needing less brain activity. Conversely, the higher activity during the proprioception task without tape would be due to the task being perceived as more difficult, thus demanding more activity to com-

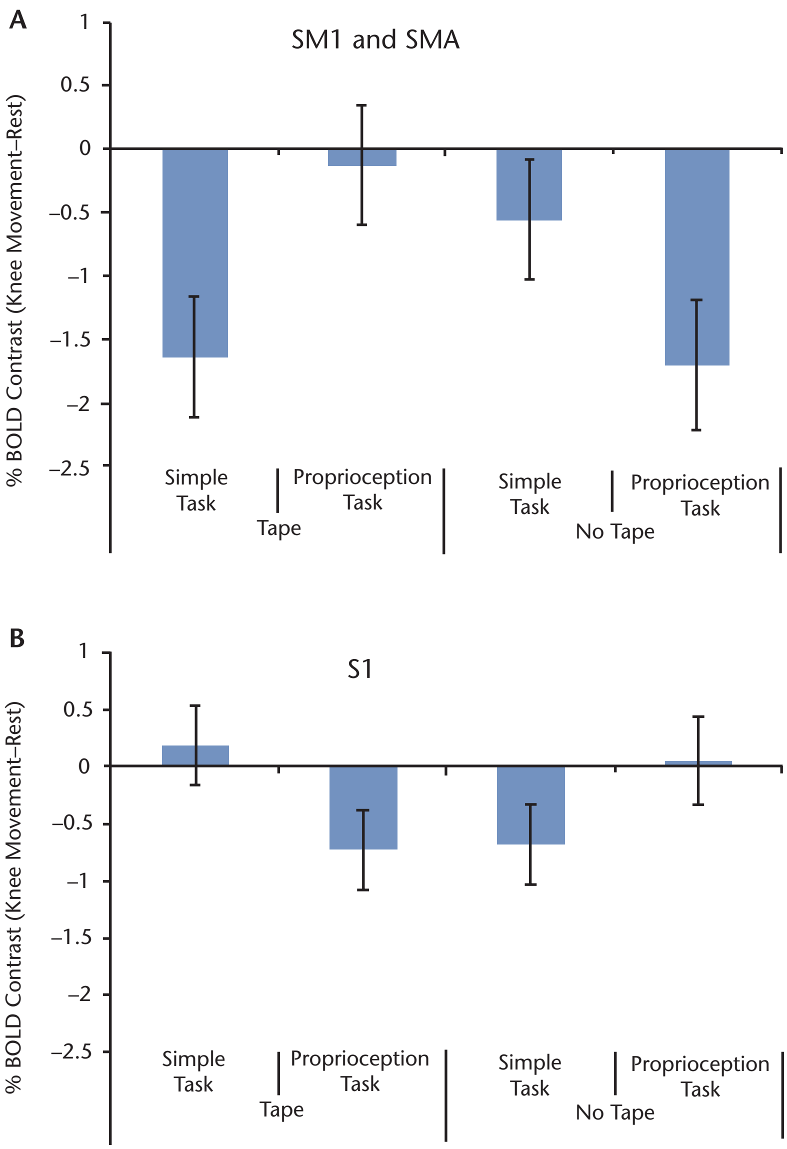

Figure 5.
Histogram showing percentage of blood oxygenation–level dependent (BOLD) contrast responses in the: supplementary motor area (SMA) and primary sensorimotor cortex (SM1) for tape (proprioception task−simple task) > no tape (proprioception task−simple task) and (B) primary sensory cortex (S1) for no tape (proprioception task−simple task) > tape (proprioception task−simple task).

plete the task. The medial SM1 also was activated in a positive direction, particularly for the proprioception task with taping, which would result in a high sensory input from both conditions combined (Fig. 4A).

In contrast to these positive BOLD responses, the lateral SM1 and SMA proper showed negative BOLD responses. The reason that these responses are still seen as increased activity, as shown by the red and yellow areas in Figure 4A, is that there is a relative *increase* in activity as they are *less* negative. This interpretation is known in fMRI studies as being "driven by a negative response." Therefore, there is a relative increase in activity in the lateral SM1 and SMA when the proprioception task is done with tape (ie, the response is *less* negative). Finding a negative response in these lateral brain areas may be due to the theory of hand-knob representation mentioned earlier. There may have been an interaction between upper-limb and lower-limb movement in the precentral gyrus and the lateral SMA, which is situated nearby.

In the lateral S1, the blue areas in Figure 4B denote a negative BOLD response when the proprioception task was done with tape. The corresponding histogram (Fig. 5B) shows there was a relative *decrease* in activity in the lateral S1 in contrast to the proprioception task without tape. Decreased activity in the lateral S1, as indicated by the blue areas in Figure 4B, seems at odds with the expected increased sensory stimulation from the tape overlying the skin, tendons, and muscles around the knee. Again, the interaction between task and tape is driven by a negative BOLD response compared with rest in the proprioception task with tape and the simple task without tape. There are 3 possible explanations why there was decreased activity in the S1. First, it is possible that the participants may have perceived the tape as hindering their proprioception task instead of enhancing it. This explanation concurs with a previous proprioception and taping study using joint position sense testing, which noted that individuals who were healthy and had good proprioception found their proprioception to be worse when tested with tape.[6] Second, it might be that the proprioception task without tape was harder to do and the brain had to increase its activity to perform this task when there was no tape, resulting in a relative *increase* in activity. Finally, the region of interest here is the precentral gyrus on S1 (Table), which lies close to the area for hand-knob representation, making possible an interaction between upper-limb movement in the precentral gyrus and S1 (Table).

Thijs et al[15] used fMRI to compare the effect of a knee brace or sleeve with a no brace or sleeve control on brain activation during right knee movement. They also found increased activity in the SM1 (Brodmann area 5), but it is difficult to compare results further, as they used female participants who flexed their knees from full extension (0°) up to 90 degrees in a nonproprioceptive, multi-joint task involving hip and ankle movement.

Clinical Implications

Clinicians have developed a variety of complex taping techniques to alter patellar position, muscle activity, or pain. This study showed that the application of a simple patellar taping technique covering 50% of skin over the knee had effects on areas of the brain associated with sensation, coordination, decision making, and planning of complex coordination tasks and the coordination of the unconscious aspects of proprioception. Currently, there are no data to demonstrate whether using a simple or complex technique has a greater or lesser effect on activity in the proprioception areas of the brain.

Limitations

There are several limitations for consideration. First, the lack of randomization of the order of taping was deferred due to technical problems, which may have introduced a learning effect. Also, as in the study by Kapreli et al,[12] a single knee joint movement was performed in contrast to the multi-joint hip, ankle, and foot joint movements involved during normal human functional tasks such as walking. The method recently used by Thijs et al[15] should encourage researchers to use a multi-joint proprioception task. Finally, the small sample of only 8 individuals who were healthy means that the results must be interpreted with caution and that studies with greater numbers of participants with and without PFPS should be considered.

Conclusion

This fMRI study has shown that there is altered brain response when a simple taping technique is applied to the right patella of individuals who are healthy during a proprioception task compared with a simple nonproprioception task. The direction of the responses does not always show increased activity and a positive BOLD response. This finding reveals a potentially nonbiomechanical effect of patellar taping during active knee movement.

Dr Callaghan, Dr McKie, and Dr Oldham provided concept/idea/research design and institutional liaisons. Dr Callaghan, Dr McKie, and Dr Richardson provided writing and data analysis. Dr Callaghan provided data collection, project management, fund procurement, and participants. All authors provided consultation (including review of manuscript before submission). The authors thank Dr Eleni Kapreli and Dr Nikolaos Strimpakos for their guidance in the early part of the study, the radiographers for their technical assistance, and the volunteers.

The study took place at the Wellcome Trust Clinical Research Facility, Manchester, United Kingdom.

Ethical approval was obtained from the Central Manchester Research Ethics Committee (No: 05/Q1404/17).

Funding for this study was provided by a Wellcome Trust Clinical Research Facility Translational Imaging Unit grant and by a National Institute for Health Research (NIHR) postdoctoral award to Dr Callaghan.

DOI: 10.2522/ptj.20110209

References

1 McConnell J. The management of chondromalacia patellae: a long-term solution. *Aust J Physiother.* 1986;32:215–223.

2 Bockrath K, Wooden C, Worrell TW, et al. Effects of patellar taping on patellar position and perceived pain. *Med Sci Sport Exerc.* 1993;25:989–992.

3 Gigante A, Pasquinelli FM, Paladini P, et al. The effects of patellar taping on patellofemoral congruence. *Am J Sports Med.* 2001;29:88–92.

4 Pfeiffer RP, DeBeliso M, Shea KG, et al. Kinematic MRI assessment of McConnell taping before and after exercise. *Am J Sports Med.* 2004;32:621–628.

5 Derasari A, Brindle TJ, Alter KE, Sheehan FT. McConnell taping shifts the patella inferiorly in patients with patellofemoral pain: a dynamic magnetic resonance imaging study. *Phys Ther.* 2010;90:411–419.

6 Callaghan MJ, Selfe J, Bagley P, Oldham JA. The effect of patellar taping on knee joint proprioception. *J Athl Train.* 2002;37:19–24.

7 Callaghan MJ, Selfe J, McHenry A, Oldham JA. Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. *Man Ther.* 2008;13:192–199.

8 Riemann BL, Myers JB, Lephart SM. Sensorimotor system measurement techniques. *J Athl Train.* 2002;37:85–98.

9 Khushu S, Kumaran SS, Tripathi RP, et al. Functional magnetic resonance imaging of the primary motor cortex in humans: response to increased functional demands. *J Biosci.* 2001;26:205–215.

10 Ugurbil K, Toth L, Kim DS. How accurate is magnetic resonance imaging of brain function? *Trends Neurosci.* 2003;26:108–114.

11 Luft AR, Smith GV, Forrester L, et al. Comparing brain activation associated with isolated upper and lower limb movement across corresponding joints. *Hum Brain Mapp.* 2002;17:131–140.

12 Kapreli E, Athanasopoulos S, Papathanasiou M, et al. Lower limb sensorimotor network: issues of somatotopy and overlap. *Cortex.* 2007;43:219–232.

13 Rotte M, Kanowski M, Heinze HJ. Functional magnetic resonance imaging for the evaluation of the motor system: primary and secondary brain areas in different motor tasks. *Stereotact Funct Neurosurg.* 2002;78:3–16.

14 Newton JM, Dong Y, Hidler J, et al. Reliable assessment of lower limb motor representations with fMRI: use of a novel MR compatible device for real-time monitoring of ankle, knee and hip torques. *Neuroimage.* 2008;43:136–146.

15 Thijs Y, Vingerhoets G, Pattyn E, et al. Does bracing influence brain activity during knee movement? An fMRI study. *Knee Surg Sports Traumatol Arthroscopy.* 2010;18:1145–1149.

16 Perlau R, Frank C, Fick G. The effect of elastic bandages on human knee proprioception on the uninjured population. *Am J Sports Med.* 1995;23:251–255.

17 Van Tiggelen D, Coorevits P, Witvrouw E. The effects of a neoprene knee sleeve on subjects with a poor versus good joint position sense subjected to an isokinetic fatigue protocol. *Clin J Sport Med.* 2008;18:259–265.

18 Elias LJ, Bryden MP, Bulman-Fleming MB. Footedness is a better predictor than is handedness of emotional lateralization. *Neuropsychologia.* 1998;36:37–43.

19 Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Am J Clin Nutr.* 1982;36:936–942.

20 Statistical Parametric Mapping. Available at: http://www.fil.ion.ucl.ac.uk/spm/.

21 Friston KJ, Williams S, Howard R, et al. Movement-related effects in fMRI time-series. *Magn Reson Med.* 1996;35:346–355.

22 Friston KJ, Josephs O, Zarahn E, et al. To smooth or not to smooth? Bias and efficiency in fMRI time-series analysis. *Neuroimage.* 2000;12:196–208.

23 Worsley KJ, Friston KJ. Analysis of fMRI time-series revisited—again. *Neuroimage.* 1995;2:173–181.

24 Debaere F, Wenderoth N, Sunaert S, et al. Internal vs external generation of movements: differential neural pathways involved in bimanual coordination performed in the presence or absence of augmented visual feedback. *Neuroimage.* 2003;19:764–776.

25 Friston KJ, Holmes AP, Price CJ, et al. Multisubject fMRI studies and conjunction analyses. *Neuroimage.* 1999;10:385–396.

26 Aminaka N, Gribble PA. A systematic review of the effects of therapeutic taping on patellofemoral pain syndrome. *J Athl Train.* 2005;40:341–351.

27 Yousry TA, Schmid UD, Alkadhi H, et al. Localization of the motor hand area to a knob on the precentral gyrus: a new landmark. *Brain.* 1997;120:141–157.