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The biomechanics of step descent under different treatment modalities used in patellofemoral pain

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Abstract

Background: Most previous work on the use of knee bracing and taping has focussed on sagittal plane movement. However, most bracing and taping techniques aim to modify patellar movement in the coronal and transverse planes.
Objective: This study investigated the effect of patellar bracing and taping on the three-dimensional mechanics of the knee during a controlled eccentric step down task.
Method: Twelve healthy subjects were asked to conduct a slow step down exercise. The step down was conducted under three randomised conditions: (a) no intervention, (b) neutral patella taping and (c) patellofemoral bracing. A step was constructed to accommodate an AMTI force platform and to produce a step height of 20 cm. Kinematic data were collected using a six camera ProReflex motion analysis system. Reflective markers were placed on the foot, shank and thigh using the Calibrated Anatomical Systems Technique (CAST).
Results: The patellofemoral brace and taping led to a significant reduction in the maximum coronal and range of torsional knee angles by 5° and 2°, respectively ($p = 0.030$, 0.006). The range of coronal and transverse plane knee moments was also significantly reduced by 0.15 Nm/kg and 0.03 Nm/kg ($p = 0.020$, 0.0019). The brace was shown to be more effective in the coronal and transverse planes in comparison to taping or no intervention.
Conclusion: Bracing and taping appear to offer coronal plane and torsional control of the knee during eccentric step descent. Coronal and transverse plane mechanics should not be overlooked when studying patellofemoral pain.
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Keywords: Patellofemoral pain; Step descent; Biomechanics; Orthotics

1. Introduction

A recent review [1] highlighted the lack of understanding of patellofemoral joint biomechanics during gait, with only 6% of papers addressing the subject. This is interesting as two widely used methods of treating this condition, patellar taping and bracing, appear well suited to investigation using a biomechanical approach. One of the problems faced by researchers in this field has been to define activities which are functionally relevant to patients and sufficiently challenging of the dynamic stability of the joint. At the same time these activities should avoid inducing pathological overload with consequent risk of injury. Gait activities involving level walking are unlikely to provide a sufficient challenge to dynamic control of the patella. Researchers are increasingly investigating variables associated with eccentric control during step descent [2–8].

Step descent is more challenging than step ascent due to the level of eccentric control required. During stair descent the centre of mass is carried forwards and then gravity is resisted during the controlled lowering phase. This is achieved through eccentric muscular contraction, which controls the rate of lowering of the centre of mass. In the absence of strong eccentric muscle activity around the knee, the centre of mass would accelerate due to gravity. In addition during the controlled lowering phase the knee joint starts from a relatively stable extended position and flexes, towards an increasingly unstable position. The increased joint flexion causes a progressive increase in the external

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flexion moment which is matched by progressively increasing eccentric muscle contraction, in order to prevent collapse. In doing so the internal extensor moment increases during descent as knee flexion occurs. This results from proximal shift of the patella contact zone due to the cam shape of the femoral condyles. This causes the patella tendon lever arm to lengthen and the quadriceps lever to shorten. The effect of the moving contact zone is significant; at angles of less than 60° knee flexion the quadriceps lever arm works with a mechanical advantage, however, at angles of greater than 60° knee flexion the quadriceps work at a mechanical disadvantage [9,10].

Since McConnell's landmark paper in 1986 [11] there has been considerable clinical and research interest in taping techniques for the patellofemoral joint. Patellofemoral taping techniques are now considered as part of standard clinical practice. Although a consensus view that tape is effective at relieving pain is emerging in the literature, there is still an ongoing debate about the mechanical effects of taping. Recent work has highlighted the importance of the proprioceptive effects of taping [12].

Research on the effects of bracing in the management of patellofemoral problems is limited compared to taping, with only 7% of the recent research literature focussing on this modality [1]. The pain relieving effects of bracing have been attributed to an increased stabilisation of the joint which reduces muscle force generation [13]. In particular patellofemoral braces are designed to ''reduce compression of the patella as well as to prevent excessive lateral shifting''[13]. Although the limited results are encouraging, patellofemoral bracing remains controversial.

It is important to note that the majority of previous research on the biomechanics of the patellofemoral joint during step descent has either focussed on the sagittal plane or used very simple marker sets [3,5,6,14,16,17]. This has lead to conflicting results. However, the knee and the patellofemoral joint both have six degrees of freedom of motion. Further, they both have moving centres of joint rotation leading to extremely complex control mechanisms. The importance of this was highlighted by Kowalk et al. [15]. They reported that although the knee abduction–adduction moment is not in the primary plane of motion, it should not be ignored when assessing the stability and function of the knee during stair climbing activities. This is also important when considering the effect of taping and bracing. These modalities usually apply forces which are directed medially. Therefore changes in mechanics would be observed in the coronal or transverse planes and not in the commonly investigated sagittal plane.

This study aimed at investigating the effect of patellar bracing and taping on the three-dimensional mechanics of the knee during a controlled eccentric step down task. It was hypothesised that the introduction of patellar bracing would alter the mechanics of the joint by reducing coronal and transverse plane movement and moments. It was also hypothesised that taping would also have an effect on kinematics and kinetics of the knee, however this would be due to proprioceptive mechanisms rather than mechanical changes.

2. Methods

The study was an experimental comparative three randomised conditions group study. The participants served as their own control with the no intervention condition being the internal control. All

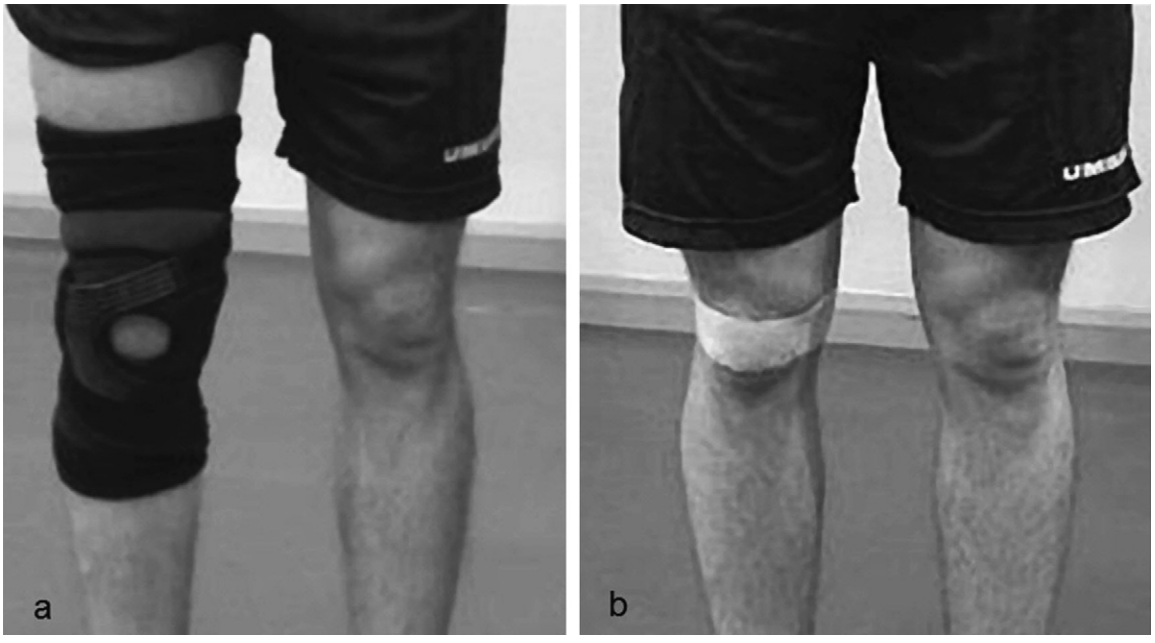


Fig. 1. The taping and bracing conditions used. (a) Trupull Advance sleeve patellofemoral brace (DJ Ortho) and (b) Neutral taping.

data collection conformed to the Declaration of Helsinki [18] with volunteers giving written informed consent prior to data collection. The study was approved by the Faculty of Health Research Ethics Committee, University of Central Lancashire.

2.1. Participants

Twelve healthy participants, with a mean age of 28 years (S.D. = 8.8 years) were recruited from staff and student populations at the University of Central Lancashire. All participants reported to be free from any pain or pathology affecting the spine or lower limbs at the time of testing.

2.2. Procedures

The purpose of the step down exercise was to assess the control of the knee as the body was lowered as slowly as possible from the step. The step down was conducted under three randomised conditions: (a) no intervention, (b) Trupull Advance sleeve knee brace (DJ Ortho), (Fig. 1a), (c) neutral patella taping (Fig. 1b). Five repetitions under each condition were performed [2].

For the application of the taping technique the subjects were supine with a relaxed, extended knee. One strip of tape was applied without tension across the centre of the patella. The tape was not pulled in either the medial or lateral direction, as recommended by previous studies [12]. Neutral taping was chosen for consistency in this study, due to its relative ease of application compared to other taping techniques. As shown by Wilson et al. [19] the direction of tape was not significant when measuring immediate pain reduction during a step down activity. The length of tape was measured using a tape at 50% of the total circumference of the subject's knee [13]. The brace Trupull Advance sleeve knee brace (DJ Ortho) was applied in accordance with the manufacturer's instructions.

Kinetic data were collected at 200 Hz using two AMTI force platforms. A step was designed to accommodate one of the plates. The other plate was embedded in the floor. This arrangement produced a standard step height of 20 cm [2,3] (Fig. 2). The force platforms (embedded in the step) allowed for the measurement of the kinetics in the sagittal, coronal and transverse planes. Kinematic data were collected using a six camera ProReflex MCU240 motion analysis system (Qualisys medical AB, Gothenburg, Sweden) at 100 Hz. Reflective markers were placed on the foot, shank and thigh using the Calibrated Anatomical System Technique [20]. Raw kinematic and kinetic data were exported to Visual3D (C-Motion Inc., USA). Kinematic and kinetic data were filtered using fourth order Butterworth filters with cut off frequencies of 6 and 25 Hz, respectively. Joint kinematics were calculated relative to the shank coordinate system. The kinematics were calculated based on the cardan sequence of *XYZ*, equivalent to the joint coordinate system proposed by Grood and Suntay [21]. Knee joint kinetics were calculated using standard inverse dynamic methods, relative to the shank coordinate system. The kinematic and kinetic data about the knee were then quantified from toe off, of the contralateral limb to contact of the contralateral limb, providing data for the supporting, eccentrically controlling limb during single limb support.

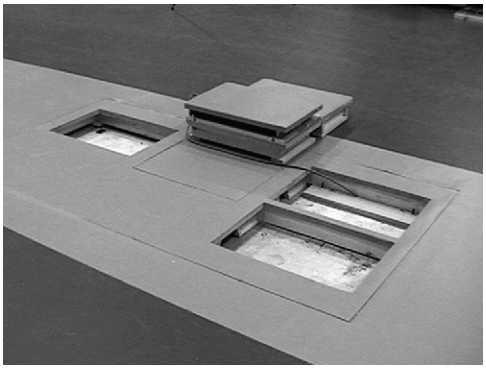


Fig. 2. Experimental setup of the force platforms.

Both taping and bracing claim to change the position of the patella in the coronal and transverse planes. Therefore this study focused on the moments and movements in these planes. However, it was important to consider the sagittal plane to allow for comparison to previous work.

2.3. Data analysis

A repeated measures ANOVA test was performed together with post hoc pairwise comparison with Bonferroni adjustment for the biomechanical parameters. These were performed for the maximum coronal plane knee angles, maximum coronal plane knee moments, the range of torsional movement about the knee and the range of torsional moments about the knee. *p*-Values were reported comparing the results of bracing, patella taping and no intervention during stair descent.

3. Results

Repeated measures ANOVA revealed no significant differences in sagittal plane knee angular velocity in terms of the mean, maximum and minimum values ($p = 0.83$, 0.25, and 0.84, respectively). These results essentially rule out any chance of differences being due to variability in descent velocity. Descriptive statistics are presented in Table 1. The maximum coronal plane knee angle was shown to be significantly reduced during the interventions ($p = 0.030$). The brace reduced the maximum knee angle from 10.7° (S.D. = 7.1°) to 5° (S.D. = 6.6°) while taping reduced the maximum knee angle to 8.1° (S.D. = 7.7°). In the coronal

Table 1
Knee angular velocities during the step decent when using the bracing, taping and no intervention

Conditions	Mean	95% confidence interval	
		Lower bound	Upper bound
Mean			
Brace	−12.66	−17.48	−7.84
No intervention	−12.43	−17.25	−7.61
Taping	−14.31	−19.13	−9.49
Maximum			
Brace	−35.61	−43.75	−27.47
No intervention	−30.89	−39.03	−22.75
Taping	−40.56	−48.70	−32.42
Minimum			
Brace	3.85	−2.22	9.92
No intervention	2.43	−3.64	8.50
Taping	4.93	−1.15	11.00

Table 2
Pairwise comparison for the coronal and transverse plane kinematics of the knee, the mean difference is reported in degrees

Comparisons		Maximum coronal angle			Range of torsional angle		
		Mean difference	Standard error	Significant[a]	Mean difference	Standard error	Significant[a]
Brace	Tape	−3.13	2.29	0.62	1.97	0.97	0.22
Brace	No	−5.70*	1.94	0.05	2.75*	0.82	0.03
Tape	No	−2.57	3.15	1.00	0.77	0.36	0.18

Based on estimated marginal means.
[a] Adjustment for multiple comparisons: Bonferroni.
* The mean difference is significant at the 0.05 level.

Table 3
Pairwise comparison for the coronal and transverse plane moments of the knee, the mean difference is reported in Nm/kg

Comparisons		Maximum coronal moment			Range of torsional moments		
		Mean difference	Standard error	Significant[a]	Mean difference	Standard error	Significant[a]
Brace	Tape	0.12	0.05	0.17	0.005	0.009	1.00
Brace	No	0.15*	0.03	0.003	0.04*	0.012	0.05
Tape	No	0.03	0.04	1.00	0.03*	0.008	0.02

Based on estimated marginal means.
* The mean difference is significant at the 0.05 level.
[a] Adjustment for multiple comparisons: Bonferroni.

plane maximum knee moment was significantly reduced during intervention ($p = 0.006$). Bracing reduced the maximum coronal plane knee moment from 0.39 Nm/kg (S.D. = 0.13 Nm/kg) to 0.24 Nm/kg (S.D. = 0.008 Nm/kg) while the tape reduced it to 0.36 Nm/kg (S.D. = 0.17 Nm/kg). Post hoc pairwise comparisons identified the differences in the maximum coronal plane knee angle and maximum coronal plane knee moment to lie between bracing and no

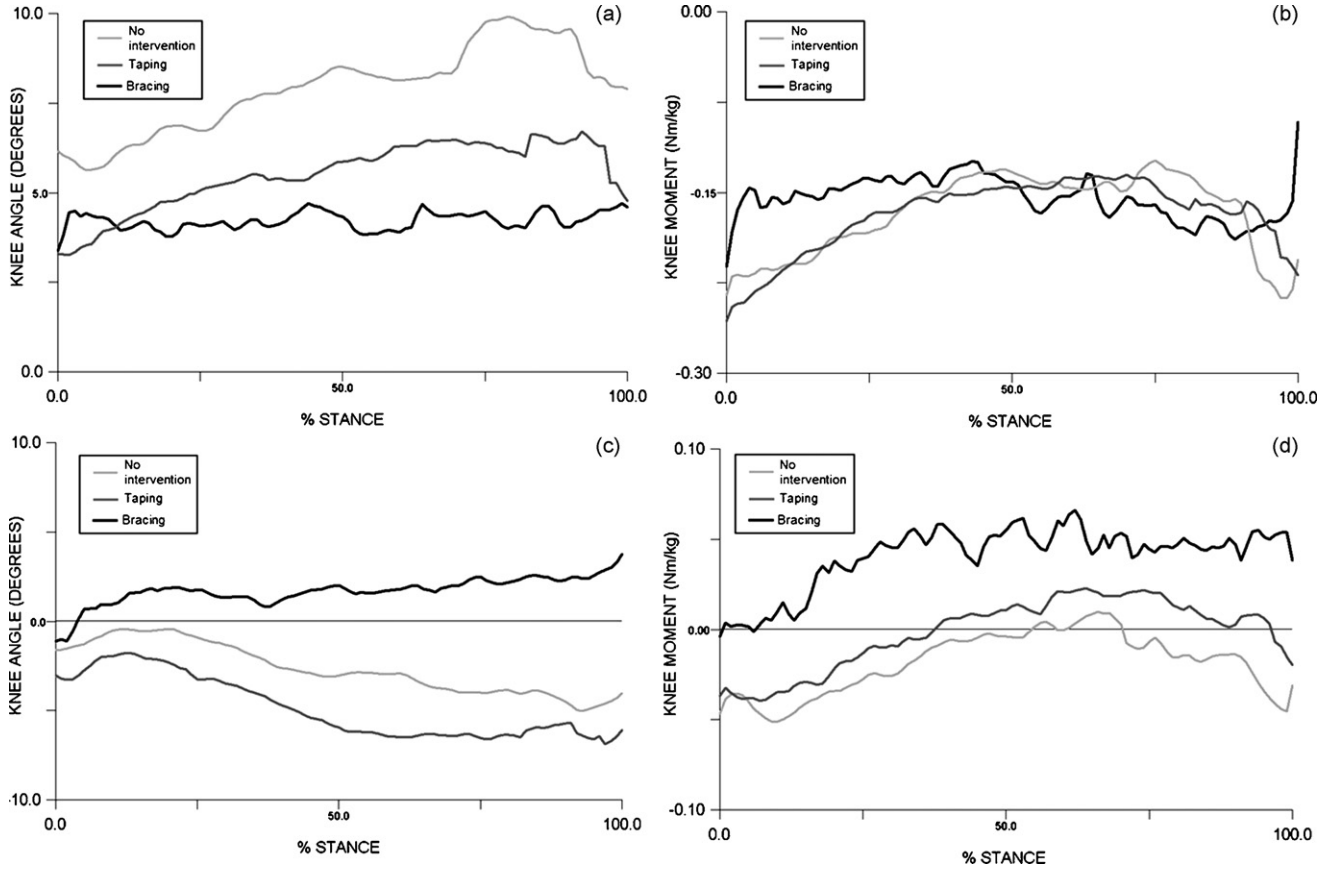


Fig. 3. Knee angles and moments during the stair descent. (a) Coronal plane knee angle, (b) coronal plane knee moments, (c) transverse plane knee angle and (d) transverse plane knee moments.

intervention ($p = 0.005$ and 0.003, respectively). The range of torsional motion was shown to be significantly reduced ($p = 0.020$) during the interventions. Bracing reduced the range of torsional angles from 8.6° (S.D. = 3.4°) to 5.9° (S.D. = 3.6°) while taping reduced it to 7.9° (S.D. = 4.2°). The range of torsional moments was shown to significantly decrease ($p = 0.0019$) from 0.121 Nm/kg (0.03 m/kg) to 0.086 m/kg (S.D. = 0.03 Nm/kg) through the introduction of the brace, and to 0.09 Nm/kg (S.D. = 0.024 Nm/kg) with the tape. Post hoc pairwise comparisons identified significant differences in the range of torsional motion to lie between bracing and no intervention ($p = 0.026$). The post hoc analysis for the range of torsional moments identified the differences to lie between bracing and no intervention, as well as between taping and no intervention ($p = 0.05$ and 0.017, respectively). Tables 2 and 3 show the results of the post hoc pairwise comparisons, while Fig. 3 shows knee joint moments and angles.

4. Discussion

The aims of the different modalities used in this study are to reduce pain and improve the control of the knee joint. Patellofemoral taping and bracing aim at influencing patella control [11,13]. This would affect coronal and transverse plane kinematics an kinetics of the knee. The reduction in coronal plane movement and moments confirmed that bracing had a significant effect on the mechanics of the knee. Similarly the results from the transverse plane showed a reduction in the range of motion and moments at the knee. The overall reduction in the range of motion about the knee can infer an improvement in joint control. However, to confirm this, further studies are required exploring the effectiveness of such orthoses on patient cohorts. Both the brace and tape had a restrictive effect about the knee, by reducing the range of torsional moments and movements. It is important to note however, that only the brace had a statistically significant effect on all the variables. This suggests that the brace was more effective than the tape.

The specific mechanisms through which the brace or tape improved control during the eccentric step descent cannot be determined from this study. There are two possible explanations of the improved control of the knee joint: neuromotor and mechanical. Both of these could be attributed to the brace. However, only neuromotor changes could be attributed to taping as a neutral technique was applied with no directional force. The greater effectiveness of the brace compared to taping may therefore be explained in two ways. The brace covered a much larger surface area of skin compared to the tape; it may be that the additional cutaneous stimulation from the brace is a significant factor in enhancing neuromotor control. Cutaneous stimulation from an elastic knee bandage has been previously suggested as an important factor in improving neuromotor control [22]. Alternatively, the directional force component applied by the brace, which was absent in the neutral taping technique, may account for the greater control seen in the coronal and transverse planes in braced subjects.

It is interesting to note that neutral taping had a significant effect in improving control of torsional moments. This could help to explain the findings of Hinman et al. [23] who found an improvement in balance using patellar taping during step down in subjects with osteoarthritis of the tibiofemoral joint. Even though the tape was applied locally to the patellofemoral joint, the effects measured in this study manifested more globally as an improved control of the whole knee. This may have important implications for patients with more widespread knee pathology, such as osteoarthritis of the tibiofemoral joint.

The significant effect of improved torsional moment is particularly interesting in the light of the neutral technique applied. This technique did not introduce any medially or laterally directed force to the patella. It is therefore surprising that mechanical changes were measured. This finding lends further support to the idea that patella taping has at least some of its effect through cutaneous sensory stimulation and confirms previous observations that neutral taping of this type can enhance neuromotor performance [12]. It should be noted however, that these results were obtained from healthy volunteer participants. We are currently replicating this work in a group of patients diagnosed with patellofemoral pain syndrome.

5. Conclusion

Most bracing and taping techniques aim to control the patella in the coronal and transverse planes. This study showed that patellofemoral bracing and taping have a significant effect on the coronal and torsional mechanics of the knee, which has not been previously identified. This led to an eccentric step descent with considerably more control. Bracing was more effective than taping. The results of this study confirm the report of Kowalk et al. [15] that coronal and torsional mechanics of the knee should not be overlooked when studying step down activities.

Conflict of interest statement

We can confirm that there is no conflict of interests for any of the authors.

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