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Validity of Visual Assessment of Sit to Stand After Hip Fracture

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Abstract

Background and Purpose—When treating older adults post hip fracture, physical therapists routinely assess the sit to stand (STS) task using observational analysis. Studies have demonstrated that significant movement asymmetries in ground reaction force production of the fractured lower limb persist during STS, even though individuals may rise independently. To date, the validity of therapist judgments of lower limb force during STS has not been addressed. The purpose of this observational cohort study was to determine the accuracy of physical therapists' observational assessments of STS for detecting the involved limb and its ground reaction force contribution in older adults post hip fracture.

Methods—Eighteen home health physical therapists assessed 10 videotapes of older adults post hip fracture rising from STS and judged the side of involvement and the amount of ground reaction force generated by the fractured lower limb. Each videotape was synchronized with its respective force data. A wide spectrum of asymmetry in rising was represented in the test videos. Prior to making these judgments, the therapists viewed a separate set of training videos and received instructions in the use of specific visual cues to assist with subsequent judgments.

Results and Discussion—Therapists judged the involved side correctly 74% of the time. Mean accuracy in judging ground reaction force output was 39% across all therapists. Force symmetry did not significantly influence accuracy of force judgments. Inaccurate judgments of force may limit therapeutic intensity and minimize the potential for developing motor strategies that favor force production of the involved limb. Augmenting observational analysis of STS with quantitative data could assist in optimizing restorative function.

Conclusion—Judgments of lower limb ground reaction force output during STS based on observation alone are not valid, and may need to be supplemented with quantitative data.

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Keywords

Hip Fracture; Sit to Stand; Movement Analysis

INTRODUCTION

Physical therapists routinely rely on their observations of older adults post hip fracture performing activity-related tasks such as rising from sit to stand (STS) to document functional status, screen for falls risk, and determine the need for physical therapy services. These observations may be completed as part of a standardized outcome measure, such as the Berg Balance Scale, the Timed Up and Go, or the Five-Times-Sit-to-Stand Test, or may be made on an ongoing basis during task-related training sessions.^{1–3} Regardless of the purpose of these observational assessments, establishing their validity as a measurement method is essential so that clinicians can make accurate inferences based on them.⁴ There is some evidence supporting the validity of observations of movement for tasks such as walking and upper extremity object transportation, but similar evidence is not currently available to validate clinical data obtained through visual analysis of the STS transition.^{5,6}

In current clinical practice, physical therapists providing care to older adults post hip fracture make frequent observations of these individuals moving from STS, a task that tends to require recovery times exceeding those for walking or stairs.⁷ Physical therapists use these observations to render judgments regarding the level of physical assistance needed to rise, the time required to complete the transition, or the individual's ability to demonstrate the key kinematic events associated with this functional task. These data, although important for making immediate decisions regarding discharge destination or the need for continued physical therapy services, may be inadequate in their ability to accurately capture an older adult's lower extremity motor skill capacity and functional use. As a result, physical therapy assessments that rely solely on these data may underrepresent residual lower limb motor deficits. This may undermine efforts to restore optimal activity and participation levels of older adults post hip fracture and limit their current and future health and safety.

Kinetic data obtained through instrumented analysis of STS in older adults after hip fracture suggest that important differences exist between the involved and uninvolved lower extremity as individuals rise.⁸ Asymmetric movement strategies have been demonstrated, with greater peak force output noted through the uninvolved lower limb.^{9,10} Persistent weakness in knee extension strength and lower extremity power, which are documented impairments after hip fracture, may contribute to the compensatory overuse of the non-fractured lower extremity. It is hypothesized that asymmetric STS movement strategies may impact an older adult's ability to rise, especially across varied environmental conditions, and may predispose an individual to balance loss and safety risk.¹⁰ For this reason, it is important for physical therapists engaged in clinical decision making for older adults after hip fracture to analyze the STS movement strategies adopted by them. Restricting clinical judgments to the sole consideration of kinematic-related variables provides an incomplete picture of recovery of this important functional task in this group of individuals.

The purpose of this study was to determine the accuracy of observational assessments of videotaped STS transitions for detecting the amount of ground reaction force generated by each lower extremity in older adults who had recently been discharged from home health rehabilitation following a hip fracture. Lower limb force judgments made by the home health physical therapists observing the videotapes were compared to ground reaction force data from each limb retrieved from instrumented analysis of the same trial. Our general hypotheses were that home health therapists: 1) would select the involved lower limb (right or left) with greater than 75% accuracy and, 2) would define ground reaction force generated by the involved lower limb (expressed as a percentage of total lower extremity ground reaction force) during a STS transition with accuracy that was equal to or less than normal side to side variation. We also postulated that home health physical therapists' accuracy in detecting side of involvement and force generated by the involved lower extremity would depend on the amount of symmetry between sides. Specifically, our final hypotheses were that therapists: 3) would be most accurate in selecting the involved lower limb when symmetry was lowest and 4) that therapists would be most accurate in quantifying the ground reaction force generated by the involved lower limb when force contribution was nearly symmetrical (approximating 50%-50% limb force on each side) or when significantly asymmetrical patterns (approximating 30%-70% limb force, involved to uninvolved side, respectively) were demonstrated during a STS transition.

METHODS

Study Design and Participants

This observational cohort study included home care physical therapist volunteers recruited from a local home health care service agency (Figure 1). Therapists were eligible for this study if they had worked with individuals post hip fracture within the home health setting. Therapists ranged in age from 30-61 years (average 41.7 years) and had 6-36 years of physical therapy employment experience (average 22.2 years). At the time of the study, 7 therapists worked full-time (40 hours/week) and 11 worked part-time (32 hours/week). The study was conducted in the summer of 2012. The study protocol was reviewed and approved by the All-College Review Board for Human Subjects Research of Ithaca College.

Videos and Ground Reaction Force Data for the Instrumented Sit to Stand Test

The synchronized videos and ground reaction force data used in this study had been collected previously as part of published and ongoing studies involving older adults post hip fracture performing a standardized STS task.⁸⁻¹⁰ From these established data sets of older adults with (n=9) and without hip fracture (n=1), 10 videos and ground reaction force readings were selected (ie. the "test" set) for therapist visual analysis. These 10 videos were specifically chosen as the test set because they were representative of the wide range of lower extremity force symmetry data that had been collected to date (n > 100) and therefore represented typical clinical practice (Table 1). The videos included one older adult control subject, representing relatively equal contributions of the involved and uninvolved limbs, 3 videos of older adults with a hip fracture with weight distribution in the range of controls, i.e. within 2 standard deviations (2SD) of controls, and 6 videos of older adults recovering from a hip fracture outside the range of controls (> 2 SD of controls). Test video selection

was based solely on lower limb force readings, assuring that researchers selecting the videos were blind to the movement strategy used by each older adult. Demographic and clinical variables describing the older adults post-hip fracture featured in the test videos are noted in Table 2.^{11–14}

The procedures to collect the synchronized video and force data during the STS transition are described elsewhere, and therefore are briefly described here.^{8–10} Each older adult was seated on the front half of an instrumented chair with the mid-length of both thighs aligned with the edge of the instrumented chair and both ankles placed at approximately 15° of dorsiflexion. Initially, the height of the seat was adjusted as close as possible to achieve a 90° angle at the hips and knees. The older adults were instructed to stand up as quickly as possible, with hands positioned across their chest. One practice trial was performed before recording data from two or three STS trials. To record force under each lower limb and determine STS phase-specific variables, 3 force plates were integrated into a custom built chair and synchronized with digital video recordings. Two force plates recorded ground reaction force (GRF) under each lower limb (involved and uninvolved). A force plate mounted on the seat recorded the force specific to the buttock and was used to determine seat off. During each data collection the vertical force generated by each lower limb was recorded at sampling rate of 1000 Hz using the Motion Monitor Software (Innsport Training, Inc., Chicago, IL). A separate digital video camera (model DCR-TRV240, Sony), synchronized with ground reaction force data, frame rate =30 samples/second, was used to acquire frontal plane video of each older adult during the STS task. The camera was mounted on a tripod that allowed for adjustment to seat height. Three levels mounted on the tripod in each plane were used to align the camera “square” with the seat, minimizing the effects of parallax. From the 4 force plates the following calculations were made to quantify the movement strategies demonstrated:

- The preparatory and rising phases of the STS task were distinguished from one another using the summed vertical ground reaction force ($vGRF_{bilateral}$) data of the involved and uninvolved lower limbs ($vGRF_{bilateral} = vGRF_{involved} + vGRF_{uninvolved}$). The rising phase began at seat off, identified as the instant the vertical force on the seat was less than 5 Newtons. The rising phase ended when the summed force ($vGRF_{bilateral}$) reached body weight, after the first peak of the summed force.
- Once the phases of the STS task were identified, lower extremity force variables were calculated. The primary variable of interest was the percent peak force of the involved side during the rising phase. This variable was chosen as our reference, as we anticipated that therapists would most likely judge the force through each lower limb at this point in the transition. The involved lower limb was defined as that with the least force output. This corresponded to the fractured limb in all but one case. The percent force of the involved side was calculated as follows:

$$\%peak\ lower\ limb\ force_{involved\ side} = \left[\frac{GRF_{involved\ side}}{(GRF_{involved\ side} + GRF_{uninvolved\ side})} \right] * 100$$

This calculation provided a symmetry measure, where 50 % peak force of the involved side represented a symmetrical trial. Using this measure, the videos chosen for the test set were classified into high, moderate, and low symmetry. High symmetry videos included those with the percent peak lower limb force of the involved side equal to 43-50%, which was within 2 SD of the variance observed in non-injured controls ($\pm 7\%$).⁸⁻¹⁰ To define low symmetry, the video with the least symmetry in the available data set was identified (video 10 = 4.9 SD from controls). This led to the subsequent selection of available videos that incrementally became more symmetrical. These videos were then split into moderate and low symmetry designations. This resulted in moderate symmetry test videos with side-to-side variability ranging from 2.3 to 3.1 SD of non-injured controls and low symmetry ranging from 4.0 to 4.9 SD of non-injured controls (Table 1).

Visual analysis training procedure

All physical therapists participated in a 30-minute standardized education and training program that was held just prior to the start of the data collection session. Training and data collection were completed at the home health agency's local office. Based on the movement adaptations observed in the test set of videos and ground reaction force data, one researcher developed the content of the training session. A separate set of training videos ($n=6$) was specifically selected because it included movement adaptations also seen in the test set of videos. The resulting education session included a slide presentation that provided a brief review of the phases of the STS task, the critical events defining each phase, and the factors contributing to symmetrical task completion. Participants were instructed to focus on 3 key parameters identified in the training and test videos to facilitate their ability to judge lower limb weight bearing forces during STS. These parameters included trunk movement at the time of lift-off from the bench, lower limb movement from the original starting position, and trunk position during the rising phase. A rating scale addressing these 3 factors, along with subsequent questions related to lower limb force symmetry, was explained, and the training videos were presented to show the participants the full spectrum of data for each factor. For each of the 3 parameters, 2 training videos were shown, with 1 video representing normal movement and the second video representing movement adaptation. Following review of each training video, a graph depicting ground reaction force readings was shown to give the therapists feedback about the actual lower limb force output. Following review of each training video, a graph depicting ground reaction force readings was shown to give the therapists feedback about the actual lower limb force output.

Immediately following the training session, the physical therapists judged the STS lower limb forces exemplified by the older adults in the 10 test videos. Therapists watched the 10 test videos in random order. Videos were played at normal speed and the therapists were able to replay the videos an unlimited number of times. The average number of times a therapist watched each video was 7, with a range of 4-12 views. Therapists watched the videos independently on laptop computers and recorded their scores.

Statistical Analysis

To address the first hypothesis that therapists would accurately determine the side of involvement using video analysis, the percent correct selections of the involved lower

extremity across all 10 videos was calculated (e.g. 8 correct equals 80%). For hypothesis 2, therapist error (absolute error) in judging the percent peak lower limb force was calculated as the absolute value of the difference in the GRF estimate and therapist estimate. If the therapist's judgment of percent peak force generated through the involved lower extremity was higher or lower than the measured GRF percent peak lower limb force, it was considered an error. An estimate of reasonable accuracy in percent lower limb force was required to provide perspective to the therapists' errors in judgment. Two standard deviations of the absolute difference in peak ground reaction force between the right and left lower limbs of non-injured controls (n=17) expressed as a percent ($\pm 7\%$) was used as a reasonable error threshold. If therapist judgments were within this error range it implied they were able to determine symmetry to controls. Therefore hypothesis 2 would be supported if a majority of therapist errors in percent lower limb force were $\leq 7\%$. To gauge if a particular video was more difficult than another, therapist errors were reported for each video.

The third and fourth hypotheses evaluated whether accuracy in involved side selection and therapist judgments of percent lower limb force depended on the amount of symmetry. The accuracy of selecting the involved lower limb (side with least force output) and judging force output was presented across therapists for each video. A chi-square test was used to assess the proportion of correct judgments for high, moderate, and low symmetry videos. A significant chi-square test suggested symmetry influences accuracy. To further address involved limb selection and percent lower limb force accuracy, a sensitivity analysis evaluating the ability of a specific subset of therapists to influence the results was pursued for each hypothesis. This analysis evaluated the accuracy per therapist for determining side and percent lower limb force. The assumption was that if an individual therapist performed significantly better than others, then it would be likely that therapist-specific factors may also be important in determining therapist accuracy.

RESULTS

Therapist judgments of side and lower limb force

The results for hypotheses 1 (therapist ability to select the involved lower limb) and 2 (therapist ability to accurately judge lower limb force) were mixed. Across all 10 videos, the 18 therapists were able to accurately select the involved limb 74% (14%) of the time, showing support for hypothesis 1 (Table 3). Side selection accuracy was $>83\%$ on 5 of the 10 videos.

However, the percent of accurate lower limb force judgments that fell within $\pm 7\%$ of the measured value was low across all therapists, with a value of 39% (18 %), a finding that did not support our second hypothesis (Table 4). Therapist accuracy in judging lower limb force was 50% or below for all but 2 videos (Figure 2). The range of therapist accuracy for judging lower limb force across videos was 0% to 67% (Table 5). The mean absolute error in judging lower limb force ranged from 5% for video 1 (control) to 19 % for video 3 (Table 5).

Influence of symmetry

Therapist accuracy for determining the side of involvement was greatest when force symmetry was the lowest (chi square = 12.9, $p < .01$), a finding that supported our third hypothesis. The accuracy for side determination increased as the force symmetry decreased, with 63%, 74%, and 91% accuracy noted when symmetry was high, moderate, and low, respectively (Table 3).

Although differences were found in the ability of the therapists to accurately judge lower limb force across videos with varying symmetry (high = 37.5%, moderate = 31.4%, and low = 50%), accuracy across any level of symmetry did not exceed 50% and the proportions were not significantly different (chi square = 4.1, $p = .13$) (Figure 2). These findings did not lend definitive support to our final hypothesis.

Influence of therapist

Individual therapists showed wide variation in their ability to judge the side of involvement (Table 3) and percent lower limb force (Table 4). Five therapists accurately selected the involved side 90% of the time, while 2 of the 18 therapists were correct 50% of the time. A total of 13/18 therapists were able to accurately judge the involved side greater than 69% of the time. When asked to judge force, 2 therapists made accurate estimations on 70% of the videos, while 5 were accurate on 20% of the videos (Table 4). Only 4 therapists demonstrated an accuracy higher than 50%. A post hoc analysis to determine the point at which therapist judgments reached >50% accuracy was completed (Figure 3). Therapist judgments that were accurate within 2 to 6 SD of non-injured controls were calculated across videos. This post hoc analysis (Figure 3) showed that a lower limb force error threshold of 3 SD (10.5%) yielded an accuracy of therapist judgments of 56%. As expected, with each SD increase in the error threshold, therapist judgments became progressively more accurate, exceeding 80% at 6 SD (21%).

DISCUSSION

The purpose of this study was to determine the accuracy of physical therapists in using visual analysis of STS to determine the side of involvement and force magnitude contributions of the lower extremities. Knowledge of the side of fracture is a key piece of data collected by physical therapists reviewing a patient's medical chart, so a therapist's ability to detect this based on observation alone has little clinical value. The physical therapists in this study were accurate 74% of the time in detecting the side of hip fracture, which very closely approximated our target value of 75%. As predicted, accuracy in side selection was highest when viewing subjects with the lowest symmetry of lower limb force production. Yet, side selection accuracy was not a guarantee, as it ranged from 50-90% across therapists. It is likely, however, that accuracy would be even higher in clinical situations where therapist observations could be augmented by patient, task, or environmental inputs and viewing angles not afforded in this video analysis. Observation-based judgments of lower limb force magnitude made by the 18 experienced therapists recruited for this study revealed a mean absolute error of 12.39%, which exceeded the error deemed acceptable at the outset of this study. No consistent pattern of errors was noted in

the judgments of individual therapists, with overestimation errors being roughly equal to underestimation errors (51% vs 49%, respectively). Some therapists were very accurate in estimating force magnitude on a few videos, yet made large errors when judging the force magnitude of the fractured lower limb on other videos (Table 4). Despite having considerable experience delivering care to those recovering from a hip fracture, less than half of the therapists (44%) accurately judged force magnitude on 50% of the videos, and no therapist's accuracy exceeded 70%. These findings occurred despite therapist participation in a standardized training program, which is not routinely available to clinicians. This imprecision in gauging limb use and force application in a task such as STS could negatively impact perceptions of current functional status and future health potential of those recovering from hip fracture by contributing to an inappropriate length of program services or intensity of programmatic components.

The range of absolute errors of force magnitude across therapists and across videos was variable (Tables 4 and 5). It is possible that as therapists viewed the videos to make their force judgments, the key movement variables they assessed were insufficient in directing their observations. This may have been a contributing factor impacting judgment accuracy, despite the targeted education in STS movement strategies that each therapist received prior to viewing the test videos. It is conceivable that certain STS movement patterns adopted by those recovering from hip fracture may be more challenging to judge than other adaptations. In situations where key STS movement features are complex or conflicting, a therapist may find it helpful to have access to quantitative force data to resolve observational discrepancies and assist in relaying accurate feedback to the patient.

Houck et al demonstrated that despite achieving an independent level in STS task performance and being discharged by their home health physical therapists, individuals post hip-fracture adopt an altered STS movement strategy compared to controls, with lower peak vertical force and a slower rate of force development on the involved lower limb.⁸ This under-reliance on the involved lower limb may be a learned pattern, similar to that seen following orthopedic and neurologic conditions such as total knee arthroplasty and stroke, respectively.^{15,16} In a study of individuals post hip fracture rising with and without arm use, Kneiss et al reported an overall reduction in lower extremity force magnitude with arm assistance.⁹ These investigators also reported a persistent asymmetry of force application, with lower vGRF and rate of force development of the involved lower extremity compared to the uninvolved lower limb in both study conditions. The authors concluded that individuals post hip fracture had sufficient capacity to achieve lower limb force application symmetry, but learned non-use strategies likely prevented this from being realized, even when the force demands of the task were reduced by arm use. If therapists are to promote strategies that favor lower limb use and force application, it seems important to be able to accurately measure progress across the episode of care. Emphasizing level of independence over movement quality and strategy may undermine the potential for more intense practice and reinforce the learned non-use phenomenon. This may contribute to the finding that following a hip fracture, lower limb physical activities of daily living status lags behind pre-fracture status.^{7,17}

Those depicted in the test videos exhibited the wide range of lower limb force symmetry that is commonly demonstrated by older adults post hip fracture who are capable of transitioning from STS independently. We anticipated that the symmetry of lower limb force application would significantly influence the accuracy of therapist force judgments, but this was not the case (Table 5 and Figure 2). Assuming that achieving lower extremity force symmetry in STS is a desirable movement goal, this finding raises questions as to the validity of visual assessments as a means of detecting change and tracking progress of the involved lower limb's force production across a home health episode of care.

Our therapist error threshold of 7% ($=2SD$) was chosen based on lower limb force symmetry variance data retrieved from a group of non-injured age-matched normal individuals. It is possible that this threshold was too stringent, leading to $<40\%$ accuracy in force judgments. To address this concern, therapist accuracy projections were calculated using wider error thresholds, as seen in Figure 3. Even when the leg force error threshold is widened to 3 SD (or 10.5%), therapist accuracy rises to just slightly better than chance (56%). To achieve therapists' force judgment accuracy exceeding either 70% or 80%, the leg force error threshold must be widened to 5 SD (17.5%) or 6 SD (21%), respectively. By accepting these higher levels of error, it would be difficult for therapists to make meaningful and valid judgments of the involved lower limb's contribution to force production in STS and to track progress over time.

Mangione et al reported that current home care physical therapy following hip fracture may be insufficient in its intensity, and that exercise principles such as specificity may not be well used.^{18,19} In a systematic review of community-dwelling older adults, Bohannon suggests that those who engage in limited daily STS transitions may benefit from interventions that specifically increase the number of repetitions of this task.²⁰ Functional STS training provides an opportunity for exercise specificity to be easily realized, but if reduced force application through the involved side is allowed to persist, a specific aspect of exercise intensity will likely be minimized. Since STS training is reported to be used by 100% of home health physical therapists working with individuals post-hip fracture, optimizing the delivery of this skill-based training would provide a reasonable avenue for contributing to functional limb use and health.¹⁸ Incorporating technology that provides assessments of movement variables such as vGRF may allow physical therapists to emphasize training strategies that optimize the involved limb's potential and consistent use. Quantitative data such as this could also be used to relay precise therapist performance expectations, engage individuals in setting personal movement and force application goals, and focus attention on motor learning strategies that promote, rather than limit, mobility, strength, self-efficacy, and adaptability across diverse environmental contexts or task demands.²¹

Limitations

The home health therapists who participated in this study based their visual judgments on videotapes offering frontal plane views of older adults post hip fracture. A sagittal plane view was not made available to the therapists. Viewing each older adult from more than one perspective might have improved therapist accuracy. In addition, it is likely that STS assessments made within the home environment might result in higher judgment accuracy,

as other environmental cues would be available to augment the therapist's visual assessment. On the other hand, the therapist participants had just one focus when observing the older adults moving from STS, and that was to assess lower limb force and use. Physical therapists engaged in clinical practice are likely to be assessing multi-system patient responses to the STS transition, such as those involving the cardiopulmonary system, in an effort to appropriately gauge and manage physiologic factors and comorbidities. This may contribute to a diminished accuracy in judging limb force and use.

In our educational sessions, we directed participants to make some key movement observations that we felt would best inform therapists about force magnitude. It is possible that the observations we emphasized were not optimal, and that other kinematic markers may have been more helpful to our participants.

CONCLUSIONS

When asked to observe videotapes of older adults post hip fracture moving from STS, home health therapists accurately judged the side of lower force output 74% of the time. Therapist accuracy in judging involved lower limb force across all videos was much lower, with accuracy values of 39% (27%). Leg force symmetry was not a significant factor influencing force judgment accuracy. Judgments of STS lower limb force based solely on observational analysis lack validity, and may lead to inaccurate conclusions that could impact rehabilitative efforts and activity-based outcomes of older adults post hip fracture.

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Figure 1.
Therapist Recruitment Flow Diagram.

Figure 2.
Percentage of Therapists' Judgments of Peak Lower Limb Force Considered Accurate
Across Videos.

* All therapist force judgments for Video 3 fell outside the error threshold.

Figure 3.
Influence of Error Threshold on Accuracy of Therapists' Judgments of Lower Limb Force.
Abbreviations: SD, standard deviation.

Table 1

Characteristics of the Test Set of Videos Analyzed by Each Therapist.

	High Symmetry					Moderate Symmetry					Low Symmetry		
	2 SD of controls					> 2 SD of controls							
	Control	2	3	4	5	6	7	8	9	10			
% Peak Force Contribution (involved lower limb)	50	45	44	43	42	41	39	36	35	33			

Abbreviations: SD, standard deviation.

Table 2

Demographic and Clinical Data of Older Adults Post-Hip Fracture Featured in the Test Set of Videos.

Demographic and Clinical Variables	Average (range)
Age, y	79 (65-85)
Gender	9 female: 1 male
Berg Balance Scale ¹¹	43 (37-56)
Activities Specific Balance Confidence Scale ¹²	61 (23-94)
Lower Extremity Measure ¹³	73 (53-95)
Comfortable Gait Speed, m/s ¹⁴	0.94 (.39-2.2)

Table 3

Accuracy of Therapists' Judgments in Selecting the Side of Involvement.

PT's	VIDEOS													# Correct per PT	% Correct per PT
	High Symmetry				Moderate Symmetry				Low Symmetry						
	1	2	3	4	5	6	7	8	9	10					
1	N	Y	Y	Y	N	N	Y	Y	Y	Y			7	70	
2	N	Y	Y	Y	N	N	Y	Y	Y	N			6	60	
3	N	Y	Y	Y	Y	Y	Y	Y	Y	Y			9	90	
4	Y	Y	Y	Y	Y	Y	N	Y	Y	Y			9	90	
5	N	Y	N	N	N	N	Y	Y	Y	Y			5	50	
6	Y	N	N	Y	Y	Y	Y	Y	Y	Y			8	80	
7	N	Y	N	Y	N	N	Y	Y	Y	N			5	50	
8	N	Y	Y	Y	Y	Y	Y	Y	Y	Y			9	90	
9	Y	Y	N	Y	Y	Y	Y	Y	Y	Y			9	90	
10	N	Y	N	Y	Y	N	Y	Y	Y	N			6	60	
11	N	Y	N	Y	N	Y	Y	Y	Y	Y			7	70	
12	N	Y	Y	N	Y	Y	Y	Y	Y	Y			8	80	
13	N	Y	N	Y	Y	Y	Y	Y	Y	N			7	70	
14	N	Y	Y	Y	Y	Y	Y	Y	Y	Y			9	90	
15	N	Y	Y	Y	N	Y	Y	Y	Y	Y			8	80	
16	N	Y	Y	N	N	N	Y	Y	Y	Y			6	60	
17	N	N	Y	Y	Y	Y	Y	Y	Y	Y			8	80	
18	Y	Y	N	Y	Y	Y	Y	Y	Y	N			8	80	
# Correct per Video	4	16	10	15	11	12	17	18	18	13			134	74% (14)% mean (SD)	
% Correct per Video	22	89	56	83	61	67	94	100	100	72					

Abbreviations: PT, physical therapist; Y, yes; N, no; SD, standard deviation.

Table 4

Accuracy of Therapists' Judgments of Lower Limb Force.

Therapist	Mean Absolute Error (Range)%	Videos Judged Within $\pm 7\%$ Error Threshold, %
1	18 (5, 44)	20
2	14 (0, 35)	30
3	10 (0, 25)	50
4	18 (5, 34)	20
5	11 (0, 25)	30
6	8 (0, 34)	70
7	14 (0, 37)	20
8	12 (0, 43)	30
9	14 (1, 32)	20
10	9 (0, 22)	50
11	7 (0, 27)	70
12	16 (3, 45)	30
13	12 (0, 34)	50
14	11 (0, 34)	50
15	11 (0, 34)	30
16	19 (6, 45)	20
17	7 (0, 20)	60
18	9 (0, 25)	60
Combined, mean /SD	12 (4)	39 (18)

Table 5

Influence of Symmetry on Accuracy of Therapists' Judgments of Leg Force.

Symmetry	Video	Mean Absolute Error (range) %	Therapists Within +/- 7% Error Threshold, %
High	1 (control)	5 (0, 10)	67
	2	15 (5, 25)	33
	3	19 (9, 37)	0
	4	9 (3, 27)	50
Moderate	5	8 (1, 21)	44
	6	9 (0, 30)	44
	7	17 (1, 43)	6
Low	8	18 (6, 44)	39
	9	14 (0, 45)	61
	10	11 (3, 27)	50
	Combined, mean/SD	12 (4)	39 (22)