The role of weightbearing in the clinical assessment of knee joint position sense

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Knee joint position sense was assessed by active tests with active limb matching responses in supine lying and in unilateral weightbearing (WB) stance using (re)positioning of the whole limb whilst focusing on the knee, and in supine lying using (re)positioning confined to the knee. Following five tests at approximately 45 degrees knee flexion in all three test conditions, position sense was found to be significantly more accurate and reliable following the WB procedure. Possible explanations are first, that during WB, the subjects were more able to assist identification of the test positions using cues obtained during movement of the knee to and from these positions. Second, a larger volume of proprioceptive afferent information may have been derived from sources outside the examined knee, and even outside the examined limb. Whilst WB joint position sense assessments are more functional, the obtained results may not characterise the capacity of the proprioceptors in and around the examined (knee) joint. Since the WB and non-weightbearing (NWB) results were not correlated, one procedure cannot be used to predict results from the others. Also, predominantly unilateral WB stance is often impractical for subjects with limited balance or WB pain. [Stillman BC and McMeeken JM (2001): The role of weightbearing in the clinical assessment of knee joint position sense. Australian Journal of Physiotherapy 47: 247-253]

Key words: Clinical Protocols; Knee; Proprioception; Weight-Bearing

Introduction

In recent years, increasing numbers of authors have recommended weightbearing (WB) tests of joint position or movement sense. They argue that WB tests are more functional, and involve all of the cutaneous, articular and muscular proprioceptors that act in concert during normal everyday activities (Andersen et al 1995, Bernier and Perrin 1998, Kiefer et al 1998). They also argue that standing WB assessments have more clinical relevance when evaluating proprioception in relation to falls (Marks et al 1993, Gilsing et al 1995, Petrella et al 1997), chronic sprained ankles (Waddington et al 1999) and other WB-specific pathologies.

Since some lower limb functions such as the swing phase of walking are non-weightbearing (NWB), as are most upper limb functions, there is justification for both NWB and WB proprioceptive assessments. However, as noted by Andersen et al (1995) and Taylor et al (1998), if the results from NWB and WB assessments are the same, or different but highly correlated, there is no need for clinicians to use both types of assessment.

Although seven studies comparing NWB with WB knee joint position or movement sense have been published previously, only one study, involving the ankle, appears to have involved a rigorous isolation of the WB effect (Refshauge and Fitzpatrick 1995). The main aspects of previous knee joint WB studies which justify further research are:

1. The obtained results were inconsistent — the authors report smaller errors during WB (Birmingham et al 1998 and 2000); larger errors during WB (Anderson et al 1995, Kramer et al 1997, Kiefer et al 1998); no significant difference (Taylor et al 1998); and inconsistent differences (Marks et al 1993).
2. The previous researchers allowed different types and amounts of WB through the examined limb — unilateral standing with hand support (Marks et al 1993); unilateral stance with some support from the opposite foot (Anderson et al 1995, Kiefer et al 1998, Kramer et al 1997); and supine lying with 15% or 21% body weight transmitted through the examined limb (Birmingham et al 1998, 2000; Taylor et al 1998).
4. No previous study has derived errors of accuracy (including over- and under-estimation) and reliability.

In the present study, comparisons were made between knee joint position sense actively tested under three separate conditions with matched positions of the hips, knees and (as far as practical) ankles: (1) unilateral WB stance - which of necessity involved positioning of the whole limb; (2) supine lying with NWB positioning of the whole limb; and (3) supine lying with NWB positioning of only the
The examiner passively moved the joint at approximately 10 degrees/second to the test position; (2) the subject attempted to identify (sense) the test position whilst holding it actively (isometrically) for approximately four seconds (a time period sufficient to allow videorecording of a stable position); (3) the examiner passively returned the joint to the starting position; then (4) the subject attempted to actively reproduce the previous position using the same limb.

Measurement of test and response positions was achieved by computer-aided analysis of videotape images recorded by one video camera, and using the automatic two-dimensional digitising software of the Peak measurement system. To facilitate this process, which included measurement of the hip and ankle as well as knee positions, light reflective reference markers were positioned along the lateral aspect of the limb (Figure 1). Justification of the reference marker positions is based on previous studies of optimum marker placement for hip and knee flexion-extension measurements by Cappozzo et al (1996), Lamoreux (1996) and Tully and Stillman (1995).

Knee flexion-extension was measured as the angle formed between straight lines joining the two thigh and two leg markers; and (plantar-) dorsi-flexion, the two leg and two foot markers. Hip flexion was measured as the slope of a straight line joining the thigh markers relative to vertical (lying subjects) or horizontal (standing subjects).

The assessment order for the three test conditions was systematically rotated throughout the examination so as to balance out possible interactive effects between adjacent procedures. All subjects were given an initial explanation and practice before formal examination. For each condition, the formal assessment comprised five test repetitions using the same target knee position (45 degrees flexion). Since the target position was subjectively judged by the examiner (BS), the actual test positions, which were precisely determined by computer analysis after completing the trials, only approximated the target. For example, the mean (SD) knee position for all WB tests was 43.7 (7.0) degrees.

To legitimise comparisons, the same hip and knee positions were used during each test condition, approximately 15 and 45 degrees flexion respectively. In the supine knee repositioning procedure (Figure 1A), the position of the relaxed hip was maintained by a padded block behind the distal thigh. The test involved the examiner passively extending the right knee to the test position from its resting position of approximately 80 degrees flexion. Since the aim of this procedure was to limit the test and response positioning movements to the knee, the relaxed foot remained motionless. Under the influence of gravity, the relaxed (unsupported) foot occupied a mean position of 28.5 (8.7) degrees plantarflexion.

The aim in the supine limb repositioning procedure (Figure 1B) was to have the subject locate the position of the knee after positioning the whole limb. In this test, the examiner raised the whole limb to approximately 15 degrees hip
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Flexion and 45 degrees knee flexion. In an effort to match the foot position in the standing procedure, the examiner also positioned the foot in as much dorsiflexion as the subjects could actively and comfortably maintain during each test, 3.1 (8.1) degrees dorsiflexion. The subjects were asked to concentrate on identifying the knee position while actively (isometrically) holding the limb position for approximately four seconds. After the examiner passively returned the limb to the starting position, each subject attempted to raise the limb to the previous position, again focusing on the knee.

For the standing WB assessments, minimum bilateral hand support was provided for balance. The subjects, with eyes closed were instructed to: (1) lift the unexamined foot from the floor; (2) slowly flex the WB limb until told to stop; (3) identify (sense) the knee position whilst isometrically holding the test position for approximately four seconds; (4) return to erect bilateral WB stance; and (5) reproduce the previous unilateral flexed position concentrating on the knee. During the WB tests, the hip and knee were close to 15 and 45 degrees, as in the two supine procedures, whilst the foot, under the influence of body weight, occupied 20.7 (6.4) degrees dorsiflexion.

**Analysis** All test and response positions were automatically digitised using the Peak measurement system from 0.5 seconds of videotape sampled at 50 Hz; ie, 25 consecutive videotape images. After high cut filtering of the raw data, the average of these 25 hip, knee and ankle positions was then calculated.

Position sense accuracy was measured as a *relative error* and *absolute error*. Relative error is the arithmetic difference between test and response positions. A negative sign was used if the response position underestimated (ie was more flexed than) the test position, and a positive sign if the test position overestimated (ie was more extended than) the test position. Absolute error is the signless arithmetic difference between test and response positions. The mean of each set of five relative errors, and five absolute errors, was then calculated. The *variable error*, which represents joint position sense reliability, was calculated as the standard deviation from the mean of each set of five relative errors.

A one-factor analysis of variance was used to compare the results from the three procedures with respect to the relative, absolute and variable errors. Scheffé post-hoc analysis was used to examine for specific differences. Linear correlations between data sets were calculated using coefficients of determination ($\rho^2$). Following all analyses, significance was set at $p = 0.05$. All data was analysed using the Statview™ II software package(b).

**Results**

Table 1 summarises the test positions and response errors from all subjects. On average, the NWB procedures produced positive relative errors (over-estimation), whereas the WB assessments produced negative relative errors (under-estimation). Figure 2, the results from an individual subject, illustrates the typical high accuracy and
Table 1. Summary of test positions and response errors following five tests of knee flexion position sense using two non-weightbearing and one weightbearing procedure. Data average = mean (SD).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Supine</th>
<th>Weight bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knee repositioning</td>
<td>Limb repositioning</td>
</tr>
<tr>
<td>Test positions (degrees)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td>15.0 (4.4)</td>
<td>16.1 (5.5)</td>
</tr>
<tr>
<td>Knee</td>
<td>44.0 (4.7)</td>
<td>49.0 (11.4)</td>
</tr>
<tr>
<td>Ankle</td>
<td>28.5 (8.7)</td>
<td>-3.1 (8.1)</td>
</tr>
<tr>
<td>Response errors (degrees)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative</td>
<td>3.4 (2.1)</td>
<td>0.8 (3.4)</td>
</tr>
<tr>
<td>Absolute</td>
<td>3.7 (1.9)</td>
<td>3.9 (2.0)</td>
</tr>
<tr>
<td>Variable</td>
<td>2.4 (1.0)</td>
<td>3.5 (1.7)</td>
</tr>
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1 Negative values represent dorsiflexion beyond the right angle (0 degrees) position.

Discussion

The WB assessments in the present study produced results which were significantly more accurate (both in relative and absolute terms), and more reliable than one or both of the NWB procedures. However, as will be elaborated below, this does not necessarily mean that knee joint position sense was better during the WB assessments.

Movement cues  The NWB knee repositioning procedure had the greatest potential for revealing the proprioceptive status of (only) the knee because it involved no movement, resistance or weightbearing of or through adjacent joints. Because the examiner slowly and passively moved the knee to and from the target position, there was also less likelihood that the subjects derived cues from these movements to assist in locating the test positions. For example, it is possible for subjects to sense the amplitude of movement of the knee to the test position, especially if it is produced actively and/or rapidly, then reproduce this amplitude, and hence the same final (test) position, during the response (Lönn et al. 2000).

Active limb movement to and from test positions is unavoidable in the WB procedure, hence there was a greater potential for the standing subjects to use movement cues. On the one hand a simple active movement to a test position is arguably more functional because it corresponds to the usual circumstances of everyday proprioceptive function. Conversely, allowing patients ready access to movement cues may allow them to mask deficient position sense at the examined joint; thereby misleading the examiner. For diagnostic purposes, clinicians should minimise movement cues.

Positioning of the whole limb In the WB procedure there was a relatively strong linear correlation between the concurrent hip and knee movements ($r^2 = 0.69$) and although the subjects were instructed otherwise, they could have reproduced the knee test positions by sensing and reproducing the hip movement. A similar argument applies to the NWB limb repositioning where the corresponding $r^2$ value was 0.57. In brief, assessments involving the whole limb may produce results which represent the subjects’ capacity to reposition joints adjacent to the one purportedly being assessed. In contrast with the hip, there was no significant correlation between the ankle and knee position during either the NWB ($r^2 = 0.05$) and WB ($r^2 = 0.09$) limb repositioning procedures, hence substitution of ankle for knee repositioning seems unlikely.

Whole limb positioning also provides the opportunity for proprioceptive feedback from adjacent joints. Conceivably, the sensory regions of the cerebral cortex may aggregate this information in deciphering the location of the knee. Some previous human and animal studies of concurrent limb joint movements support this proposition (Cordo et al. 1995, Verschueren et al. 1999, Abelew et al. 2000). A similar contribution to locating the knee joint position may stem from the skin of the WB foot (Kavounoudias et al. 1998). Also, because of the foot dorsiflexion during both limb...
Repositioning procedures, there is the possibility that calf (especially gastrocnemius) stretch may also be influential (see consideration of the study by Refshauge and Fitzpatrick 1995 below).

**Weightbearing versus NWB** Weightbearing may augment the afferent discharge from compressed mechanoreceptors in connective tissue structures distributed throughout the WB joints. The finding in the present study of smaller absolute and variable errors during the WB as compared with the NWB limb repositioning procedure tends to support this view, however there are other possible explanations for the differences, including the relatively greater and differently distributed muscular resistances in standing (to be discussed below).

In a specific study of WB versus NWB procedures, Refshauge and Fitzpatrick (1995) examined the threshold for detection of low velocity passive ankle movements. With the knees straight and the feet dorsiflexed in WB standing compared with the same joint positioning in NWB sitting, no significant difference was found between the two sets of results. However, when the knees were flexed in NWB sitting, the perception threshold increased approximately twofold. Refshauge and Fitzpatrick (1995) concluded that the foot and knee postures, including calf stretch, were the major determinants of the WB (and NWB) test results, and not WB as such. Because of the greater dorsiflexion, the WB procedure of the present study would also have involved greater calf stretch than the NWB limb repositioning procedure. Thus, although the results from the present study are not conclusive, they do not contradict the findings of Refshauge and Fitzpatrick.

**Resisted muscle contractions** The WB procedure was associated with greater (body weight) resistance of muscles throughout the lower limb than the (limb weight) resisted NWB limb repositioning procedure. Even less (leg-weight quadriceps) resistance was involved in the NWB knee repositioning. Whether the magnitude and distribution of muscle contractions augments or interferes with proprioceptive acuity is unclear. On the one hand, even the slightest resistance substantially increases the afferent output from muscle spindles (Wilson et al 1997), which supports the generally-accepted view that active joint position sense tests produce better results than passive tests (Craske and Crawshaw 1975, Velay et al 1989). On the other hand, no change in elbow position sense was demonstrated when Darling and Hondzinski (1999) loaded the forearm during their joint position sense assessments. Also, threshold detection of elbow movement was diminished when Wise et al (1998 and 1999) invoked contraction of the surrounding muscles. Thus, at present it can only be hypothesised that differences in the magnitude and distribution of resisted muscle contractions might affect WB versus NWB results.

**Fingertip or opposite foot support** All subjects in the present study required at least minimal bilateral fingertip support, but usually more, in order to maintain stable test and response positions in unilateral WB stance. Clapp and Wing (1999) and Rabin et al (1999) demonstrated that even fingertip contact insufficient to constitute physical support significantly diminishes sway in unilateral and bilateral stance with eyes closed. They proposed that this arose from proprioceptive feedback from skin of the supporting fingertips, and joints within the supporting limbs. The same mechanism probably applies if balance is maintained by light contralateral floor contact as in the WB tests of Andersen et al (1995) and others. Most recently, Lackner et al (2000) found that light fingertip contact can completely compensate for disturbed proprioception at the ankle produced by vibrating the surrounding muscles. This raises the question of whether fingertip or contralateral foot contact might invalidate all examinations for pathologically disturbed knee or ankle proprioception in predominantly unilateral WB stance.

**Weightbearing tests of abnormal versus normal knees** The question remains, to what extent do the findings from the current study of healthy joints apply to examination of pathological joints? Based on the arguments thus far, proprioceptive afferent information from a wide variety of sources during WB assessments might diminish or fully compensate for disturbed proprioception in, for example, an osteoarthritic knee. Marks et al (1993) found better joint position sense in osteoarthritic knees when WB in standing compared to when NWB in standing. Kramer et al (1997) compared a sitting active NWB knee repositioning procedure with a unilateral WB standing assessment in subjects with patellofemoral pain syndrome. Having found that the errors in sitting were significantly less than those in standing, Kramer et al (1997, p. 116) suggested that “during standing tests, multiple sources of information… may have confounded replication of knee angle by providing an overload of information”. If this is true, such overload would be least in the NWB knee repositioning procedure of the present study. In addition to these possible confounding influences, some standing patients might be distracted from the knee repositioning task by either the balance requirements of the procedure, or increased WB pain. Resolution of these issues obviously requires further research.

At present, it seems that WB assessments of proprioception might have greatest relevance in the area of sports medicine where relatively healthy subjects are more likely to be able to meet the WB assessment requirements, and where clinicians should be particularly interested in their subjects’ proprioceptive and balance capacities under WB functional conditions. However, such assessments should not be used as a substitute for NWB single joint positioning assessments which are likely to be more specific for the examined joint.

**Conclusions**

Active knee joint position sense assessments in unilateral WB stance with eyes closed and hand support produced more accurate and reliable results than NWB assessments in supine lying.
Active NWB knee joint position sense assessments involving knee repositioning were more reliable, but not more accurate than the NWB assessments with limb repositioning.

There was no correlation between the errors derived from the three procedures investigated.

Although WB assessments are more functional, they may not represent a valid or reliable measure of joint position sense at any individual lower limb joint.

Footnotes (a)Peak Performance Technologies Incorporated, 7388 South Revere Parkway, Suite 601, Englewood CO 80112, USA. (b)Abacus Concepts Inc, 1984 Bonita Ave, Berkeley CA 94704.

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