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The Effect of Age-Related Declines in Proprioception and Total Knee Replacement on Postural Control

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Background. An experiment was designed to examine the effects of a decrease in threshold joint position sense (TJPS) at the knee and ankle and of total knee replacement (TKR) on postural control in older adults. It was hypothesized that older adults with a decrease in TJPS and those who had undergone TKR would display increased center of pressure (COP) variance during quiet stance and late onsets for muscle responses to balance threats.

Methods. Older adult subjects (≥70 years) were evaluated and grouped according to the status of their ankle and knee threshold joint position sensation as well as their surgical history. COP data were collected while subjects stood on a force plate with feet together under eyes-open and -closed conditions. Threats to balance were given using a platform that moved forward and backward.

Results. Older subjects with poor knee extension TJPS had significantly increased COP variance, although those with very poor knee flexion and extension TJPS demonstrated even greater increases. Similarly, subjects with decreased ankle TJPS demonstrated increased COP variance. However, reduced TJPS did not affect the ability of subjects to respond to threats to balance. Post-TKR subjects showed no reductions in any aspect of postural control.

Conclusions. This study showed that the task of standing quietly has a direct relationship to threshold JPS, although the task of recovering from an abrupt perturbation does not. Older adult TKR results suggest that there is no negative effect on balance from elective joint replacement.

WITH age, the task of maintaining balance becomes increasingly difficult, as evidenced by the high frequency of falling in older adults (1). Five percent of the falls suffered by older adults are associated with a fracture, serious injury, or death (2). With advanced age comes an increase in the susceptibility to, and occurrence of, disease. Disease and/or age-related deterioration of the nervous or musculoskeletal systems may be at the root of the increased incidence of falls in the older adult population (3).

It has been proposed that deterioration in postural control in older adults emerges as the result of interactions among balance systems (e.g., sensory, motor, higher level adaptive systems) that have been affected by pathology and/or the aging process (4). If a component of the posture control system becomes compromised, so may the ability to maintain balance. The visual, vestibular, and somatosensory systems provide the necessary sensory information for the maintenance of upright posture. The somatosensory system, and specifically, the proprioceptive system, is critically involved in the sensory control of balance (5). Although considerable research has been performed concerning balance problems in older adults, little research has focused on the specific deficits in proprioceptive system function that might contribute to these problems.

A person's ability to subjectively assess the angle of a joint using proprioception is known as joint position sense (JPS), which derives input from muscular, capsuloligamentous, and cutaneous receptors (6). Of these sensory modes, it appears that JPS is derived primarily through input from receptors within muscle-tendon units (7–10).

Evidence in favor of a role for joint mechanoreceptor input to JPS comes from the observation that patients suffering from osteoarthritis show a decrease in JPS. It is presumed that this is caused by a detrimental effect of osteoarthritis on the joint capsule and articular mechanoreceptors (11–13). Even though it is generally accepted that muscle receptors provide the primary feedback for JPS, the role of the ligamentous and joint capsule receptors cannot be disregarded. There are two widely accepted methods for measuring JPS: a joint angle reproduction task and a test of threshold to sensation of joint motion (13). The threshold joint position sense (TJPS) test has been employed in this study.

Research has shown that after total knee replacement (TKR), patients demonstrated improved JPS, when compared with osteoarthritic patients who did not elect for TKR. However, JPS abilities did not return to normal, prearthritic levels after TKR. Also, surgery utilizing semiconstrained knee replacements, which maintained the integrity of the joint capsule and ligaments, has resulted in patients having slightly better JPS than those who had TKR including capsulectomy (12). Cutaneous sensory receptors have also been shown to contribute to JPS (12,14) and to posture control (15,16).

Because research has shown that the somatosensory system contributes to balance control (5,17), it is interesting to consider that older adults typically have a certain degree of decreased peripheral somatosensation (proprioception) and to consider if this is related to their observed postural dyscontrol. Whether there is a correlation between these two age-related changes in postural control and proprioception is an issue which is at the heart of this study.

The precise role of JPS in posture control is unclear. In addition, the extent of contribution of proprioception from the knee to posture control in comparison with the proprioception from the ankle is unclear. Even though there is much research on the balance abilities of young and older adults, there is very little on the balance control of those with decreased JPS.

The primary purpose of this study was to further define the role of proprioception as an integral sensory system contributing to posture control and to determine if a decrease in JPS at the knee and ankle is a main contributing factor to the observed postural dyscontrol in older adults. The secondary purpose of this study was to determine if there is an effect of TKR on postural control. It was hypothesized that subjects who display decreased knee and/or ankle TJPS and those who had undergone TKR would demonstrate (i) reduced ability to balance during quiet stance (as measured by increased center of pressure variance) and (ii) reduced ability to respond to unexpected threats to balance (measured by increased onset latencies of their automatic postural responses) as compared with those with good TJPS.

Methods

Twenty-two men and women, 70 years of age and older, were asked to participate in this study. Subjects were recruited by physician referral, advertisement, and word of mouth from within the community. Prospective subjects were required to complete a questionnaire on their medical history. Candidate subjects were interviewed and received a preparticipation examination. As part of the clinical examination, all subjects underwent testing for TJPS at the knee and ankle joints using a method for detecting threshold to detection of passive motion. This method was chosen because of its slow, passive nature, not requiring a subject to actively move his or her joint, but requiring a subject to sense his or her joint's position, and any change thereof, as they remain still in quiet stance on a force plate or just prior to a balance perturbation (described later). TJPS is a test of sensory sensitivity rather than positioning accuracy and, of the two most widely used tests, the one most analogous to the subtle bodily sway motions experienced during quiet stance.

Results of this testing were used to quantify each subject's proprioceptive abilities. A bench similar to that described by previous researchers (6,13) was used to perform TJPS testing. Subjects were positioned comfortably, blindfolded, as they underwent unilateral TJPS testing at the knee and ankle of their dominant (for controls) or surgical (for patients) leg. Their legs were fastened into the apparatus with soft Velcro straps. An air bladder, inflated to a comfortable level (approximately 20 mm Hg), surrounded the limb under the Velcro straps to eliminate sensation of movement between the strap and skin (Figure 1).

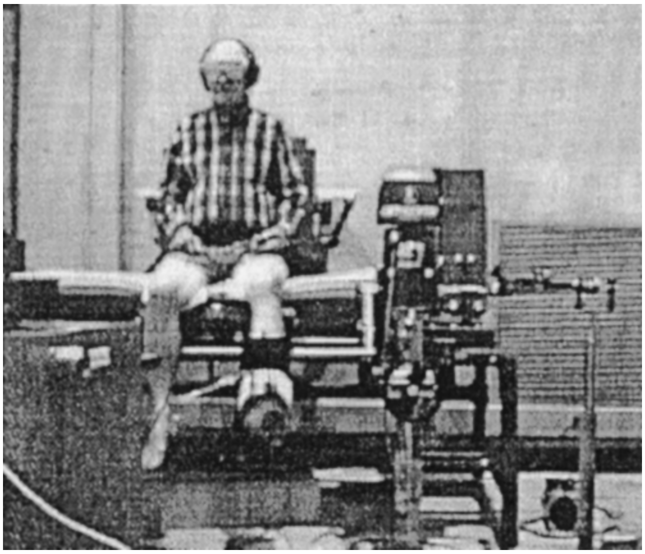

Figure 1. The joint position sense testing apparatus used to determine a subject's threshold to detection of passive motion of the ankle and knee.

TJPS of the knee (flexion and extension) and ankle (plantar- and dorsiflexion) was assessed while the subjects lay on the bench; movement of the joint was passively initiated at a speed of 0.40°/second, via an electric motor, starting at a time unknown to them. Subjects were instructed to press a "stop" button at the moment they detected movement in the joint. Performance was measured in degree of joint rotation that occurred prior to their sensing movement and pressing the stop button. These data were then used to categorize subjects into groups according to their TJPS abilities of the knee and ankle.

An AMTI force plate (Advanced Medical Technology Inc, Newton, MA) was used to collect center of pressure (COP) data. The plate consisted of a stationary 51 cm × 46 cm steel plate with implanted strain gauges. The plate was capable of measuring the forces applied to it by gravity and the movement of the subject. Subjects were required to fold their arms in front of them and stand on the surface of the plate barefooted, with feet together, for three trials (30 seconds each) with eyes open and three trials with eyes closed, while COP data were collected using a computer.

A platform, such as that used by Nashner, was used for balance perturbation trials. This was a 46-cm square moveable surface with implanted strain gauges (18). It was capable of producing abrupt horizontal translations in the forward and backward directions. This platform was used to unexpectedly disturb the subject's balance and elicit automatic postural responses. Total movement of the platform in both directions was 3.80 cm, a distance of 8.2% of the supporting platform area, at a speed of 20 cm/s. The platform was triggered through a computer while electromyographic (EMG) feedback from each subject was recorded. Subjects were fitted into a safety harness and were required to stand on the platform, arms folded, while it underwent 16 random trials of anterior and posterior horizontal translations. The subjects viewed an eye-level oscilloscope that provided left-right leg weightbearing biofeedback to assist them in stand-

Table 1. Experimental Groups

	Knee Extension	Knee Flexion	Ankle Dorsi	Ankle Plantar	*n*
Good minimum	0.73	0.66	0.55	0.55	10
Good maximum	1.75	1.54	1.25	1.78	10
Poor minimum	1.77	1.64	1.42	2.28	12
Poor maximum	12.22	15.00	4.76	10.00	12
Very Good minimum	0.73	0.66	0.55	0.55	6
Very Good maximum	1.13	0.86	0.80	0.97	6
Very Poor minimum	2.99	4.02	3.11	3.64	6
Very Poor maximum	12.22	15.00	4.76	10.00	6

Notes: Experimental groups as determined by threshold joint position sense (JPS) scores (in degrees). Minimum and maximum values of threshold JPS for subjects in their respective groups (Good vs Poor and Very Good vs Very Poor) are represented.

ing evenly weighted. There was a 20–30 second intertrial rest period. Foot placement was standardized to the width of the subject's pelvis, in line with the movement of the platform. A research assistant stood behind subjects during each trial. During each platform trial, compensatory EMG activity (of the automatic postural response) from the tibialis anterior (TA), quadriceps (Q), abdominal (AB), gastrocnemius (G), hamstrings (H), and paraspinal (PS) muscles from their dominant or surgical leg was low-pass filtered, rectified, and recorded using preamplified surface electrodes.

ANALYSIS

Four variables were measured as subjects stood quietly on the force plate. Both anterior and lateral COP displacement amplitude (mm) and velocity (mm/s) were measured with eyes open and closed. The root mean square value was calculated for each COP variable to provide a positive value for comparisons. Platform perturbation trials produced automatic postural response EMG traces that were analyzed for the onset latency (ms) of their respective anterior (TA, Q, and AB) and posterior (G, H, and PS) muscle groups.

Comparisons of COP and EMG data from 22 subjects were made. Subjects were divided into four groups. These included subjects only with good or poor (subjects in upper vs lower half on TJPS scores) TJPS of the knee and subjects only with good or poor TJPS of the ankle. These subjects were further categorized into extreme groups of only those who had very good TJPS and very poor TJPS (subjects in the upper vs lower thirds on TJPS scores). Table 1 depicts the minimum and maximum TJPS values of subjects in their respective groups. Subjects presenting with TJPS values of the knee and ankle outside the specific group ranges were excluded. Comparisons of postural control variables were also made between those subjects who had undergone TKR and those who had not.

RESULTS

Knee Group

When comparing subjects with good knee extension TJPS with those demonstrating poor knee extension TJPS, the poor group showed significantly increased anterior-pos-

Table 2. COP Root Mean Square (rms) Values of Subjects With Very Good Versus Very Poor Knee Flexion and Extention Threshold Joint Position Sense (TJPS)

	Very Good (eyes open)	Very Poor (eyes open)	Very Good (eyes closed)	Very Poor (eyes closed)
Extreme knee flexion groups				
A-P Acp *M*	0.72	1.06	0.94	1.88
SD	0.27	0.18	0.42	0.47
Lateral Acp *M*	0.81	1.23	1.02	1.98
SD	0.35	0.20	0.56	0.51
A-P Vcp *M*	14.38	21.22	18.80	37.50
SD	5.40	3.70	8.40	9.38
Lateral Vcp *M*	16.10	24.50	20.40	39.60
SD	7.00	4.00	11.20	10.25
Extreme knee extension groups				
A-P Acp *M*	0.58	0.95	0.67	1.62
SD	0.06	0.22	0.10	0.60
Lateral Acp *M*	0.67	1.20	0.75	1.87
SD	0.19	0.31	0.19	0.69
A-P Vcp *M*	11.50	19.00	13.35	32.47
SD	1.12	4.43	2.00	11.90
Lateral Vcp *M*	13.30	23.96	15.00	37.00
SD	3.80	6.24	3.70	13.60

Notes: COP = center of pressure; A-P = anterior-posterior. COP rms values (*M* and *SD*s) of subjects with very good versus very poor knee flexion (A) and extension (B) TJPS. COP amplitude (Acp) and COP velocity (Vcp) values are in mm and mm/s, respectively. All good versus poor comparisons are significantly different; $p < .05$.

terior (A-P) COP displacement amplitude (0.74 mm ± 0.24 mm to 0.98 mm ± 0.26 mm; $p < .05$) and velocity (14.8 mm/s ± 4.83 mm/s to 19.65 mm/s ± 5.26 mm/s; $p < .05$) with eyes open. No difference was observed in the eyes-closed condition. Subjects with poor knee flexion TJPS showed no difference in the control of their COP during quiet stance. Subjects with very poor (lower third) knee flexion or extension TJPS demonstrated significant postural dyscontrol in terms of all measured COP variables when assessed during quiet stance (Table 2). Subjects with very poor knee flexion TJPS demonstrated significantly increased lateral and A-P COP amplitude and velocity with eyes open and closed compared with those with very good knee flexion TJPS ($p < .05$, $df = 12$). Figure 2A shows the differences found in amplitude between the groups of subjects. Similar results were found for knee extension TJPS (Figure 2B).

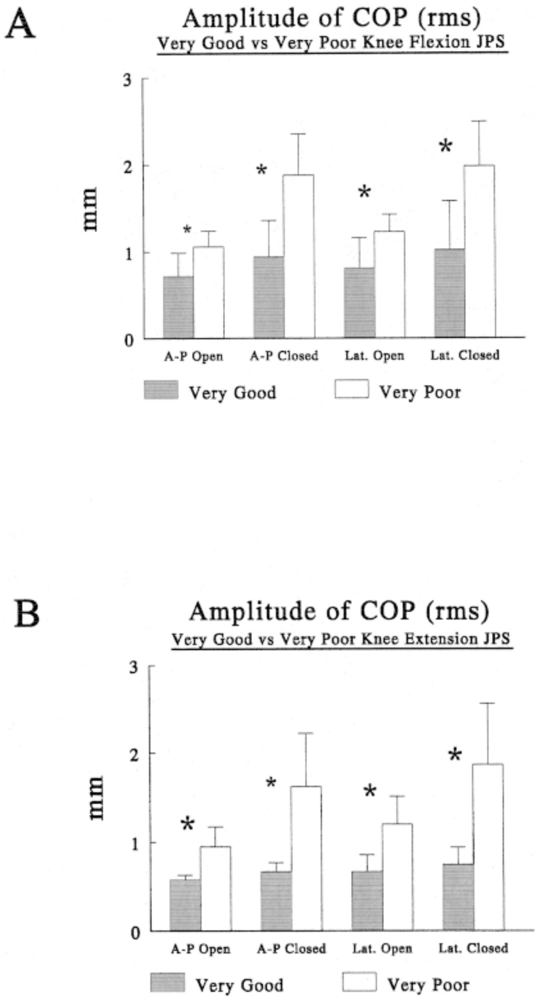

Figure 2. **A**: Graph showing amplitude of center of pressure (COP) displacement in subjects with very good and very poor knee flexion threshold joint position sense (JPS). Means and standard deviations for each group in conditions with eyes open and closed are represented. **B**: COP displacement amplitude [root mean square (rms)] in subjects with very good and very poor knee extension threshold JPS. Eyes open and closed conditions are represented. $p < .05$.

Subjects with very poor knee flexion or extension TJPS also demonstrated a relative visual dependence when they switched to standing on the force plate with eyes closed. Figure 3A depicts the COP movement patterns for a subject with very good knee extension TJPS with eyes open versus eyes closed. Figure 3B shows COP movement patterns for a typical subject with very poor knee extension TJPS while eyes are open and closed. Note the large increase in sway path during the eyes-closed condition for the subject with very poor knee extension TJPS.

The eyes-closed condition caused subjects with very poor knee extension or flexion TJPS to sway with more COP displacement amplitude and velocity than those with very good extension TJPS in the lateral and A-P directions ($p < .05$). Figure 4A depicts the relative visual dependence found in subjects with very poor knee extension with regard to the lateral ($p < .005$, $df = 10$) and the A-P ($p < .007$, $df = 10$) amplitudes of COP. Figure 4B depicts the relative visual dependence found in subjects with very poor knee flexion TJPS for the eyes-closed conditions as compared with the eyes-open conditions with regard to the lateral ($p < .008$, $df = 10$) and the A-P ($p < .004$, $df = 10$) velocities of COP. These findings, obtained from comparing the very good versus very poor groups, demonstrate the dramatic negative effect of an extreme decrease in knee TJPS on postural control as compared with the effect observed in subjects with only poor knee TJPS.

Ankle Group

As was found for subjects with poor knee TJPS, older adults with poor (lower half of subjects) ankle TJPS demonstrated significant differences in the control of their COP during quiet stance when compared with subjects with good ankle TJPS. When subjects demonstrating poor ankle plantar flexion TJPS stood on the force plate, with eyes open and closed, they showed significant increases in COP A-P and lateral sway amplitude and velocity (Table 3). Subjects with poor ankle dorsiflexion TJPS showed significant increases in lateral COP amplitude and velocity, but not in A-P amplitude or velocity (Table 4).

Again, categorizing subjects into extreme groups of very good and very poor TJPS demonstrated significant differences between groups. Those subjects with very poor ankle plantar flexion TJPS demonstrated significantly increased A-P and lateral COP amplitude and velocity across conditions compared with those with very good ankle plantar flexion TJPS ($p < .05$) (Table 5). Subjects with very poor ankle dorsiflexion TJPS demonstrated significantly greater lateral COP amplitude with eyes open (0.78 mm/s ± 0.33 mm/s to 1.13 mm/s ± 0.10 mm/s; $p < .05$) as well as greater lateral COP velocity (15.52 mm/s ± 6.70 mm/s to 22.69 mm/s ± 2.00 mm/s; $p < .05$) when compared with their counterparts with very good ankle dorsiflexion TJPS. They did not demonstrate visual dependance when eyes were closed. As seen when examining subjects in the good versus poor groups, subjects with very poor ankle dorsiflexion showed differences, yet not to the same extent as did the plantar flexion cohorts.

Although subjects with an extreme decrease in ankle dorsiflexion TJPS did not demonstrate visual dependence, those

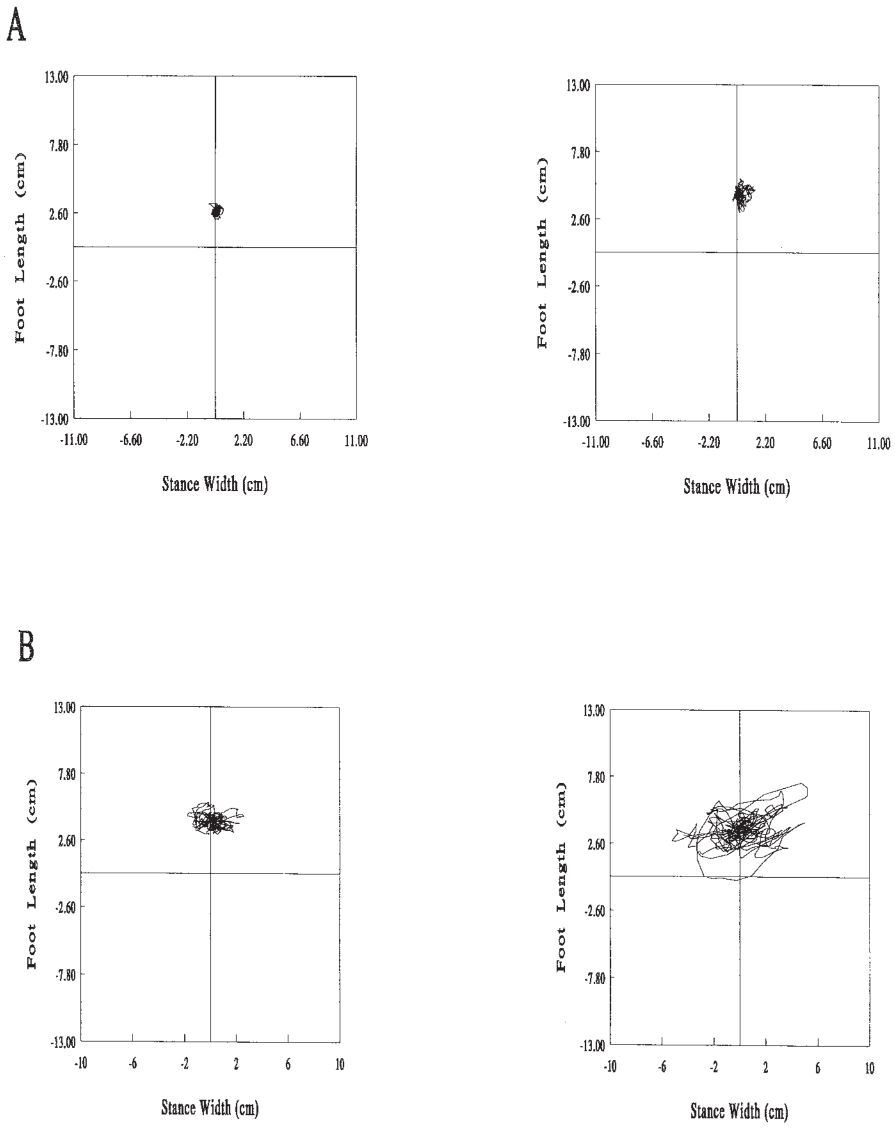

Figure 3. Quiet stance center of pressure (COP) displacement patterns of two subjects during a 30-second trial. **A**: Subject with very good knee extension threshold joint position sense (TJPS) with eyes open (left panel) versus eyes closed (right panel). **B**: Subject with very poor knee extension TJPS with eyes open (left panel) versus eyes closed (right panel).

with very poor plantar flexion TJPS did when they switched to standing on the force plate with eyes closed (with regard to the lateral, $p < .00003$, $df = 10$, and the A-P, $p < .001$, $df = 10$, amplitudes of COP) (Figure 5). This condition caused subjects with very poor ankle plantar flexion TJPS to sway with more COP displacement amplitude than controls in the lateral (0.55 mm compared with 0.08 mm; $p < .05$) and A-P directions (0.67 mm to 0.10 mm; $p < .05$). This group also demonstrated increased velocity of COP movement in the lateral (11.04 mm/s compared with 1.17 mm/s; $p < .05$) and A-P directions (13.30 mm/s to 2.05 mm/s; $p < .05$) (Figure 6).

Automatic Postural Response Latencies

Analyzing data from perturbation platform trials showed that a decrease in knee or ankle TJPS has no effect on a subject's automatic postural response. Although rapid and synchronous electrical activity of the anterior (TA, Q, and AB) and posterior (G, H, and PS) muscle groups can have a compensatory and corrective effect to a balance disturbance, no significant difference was found between experimental groups in terms of anterior or posterior automatic postural response latencies for subjects with decreased TJPS of the knee (Figure 7A) or of the ankle (Figure 7B).

Total Knee Joint Replacement

All measurements of TJPS showed no significant differences between patients who had undergone TKR and controls when testing the knee or ankle. TJPS of the knee and/or ankle was not affected by TKR in any range of motion, either knee flexion ($p < .53$, $df = 24$), knee extension ($p <$

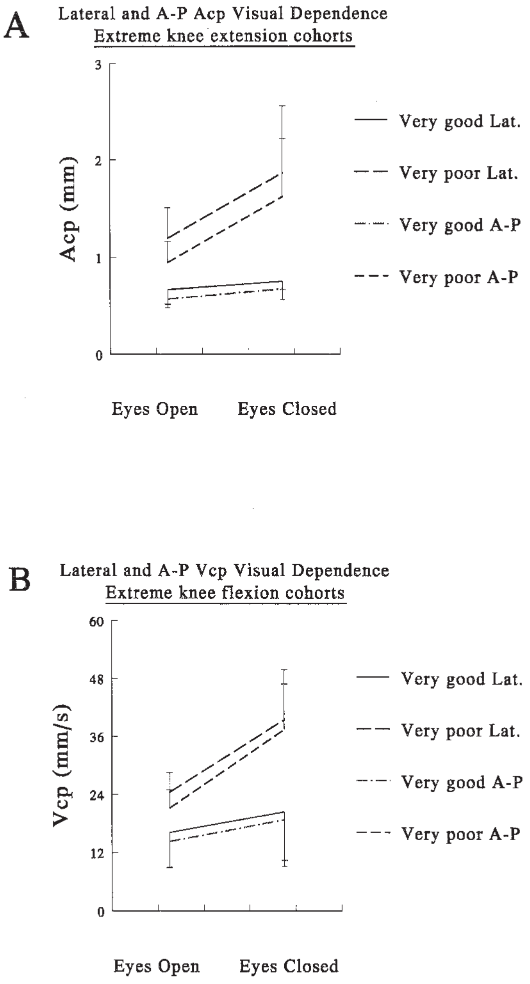

Figure 4. Graph showing visual dependence, or the increase in root mean square center of pressure (COP) amplitude (Acp), from eyes-open to eyes-closed conditions for **A**, subjects with very good versus very poor knee extension threshold joint position sense, and **B**, subjects with very good versus very poor knee flexion threshold joint position sense. Lat = lateral; A-P = anterior-posterior.

.12, $df = 24$), or ankle plantar flexion ($p < .29$, $df = 22$) or dorsiflexion ($p < .53$, $df = 22$).

As did a decrease in TJPS, TKR also proved to have no effect on the automatic postural response muscle onset latencies. Data collected from platform trials demonstrated no significant difference between experimental cohorts with regard to EMG onsets of the anterior or posterior muscle groups. Comparisons of anterior muscles of TKR patients versus controls showed no significant difference: TA, $p < .78$, $df = 19$; Q, $p < .81$, $df = 20$; and AB, $p < .34$, $df = 12$. A similar comparison of posterior muscles showed no significant difference: G, $p < .70$, $df = 20$; H, $p < .80$, $df = 19$; and PS, $p < .30$, $df = 19$. Both experimental groups demonstrated characteristic, ascending automatic postural response synergy patterns in anterior and posterior muscles.

In addition, tests of postural stability on TKR patients during quiet stance showed no differences with regard to the variance of COP amplitude in the A-P or lateral directions while subjects stood with eyes open or closed [A-P amplitude of center of pressure (Acp) eyes open: $p < .62$, $df = 21$; eyes closed: $p < .82$, $df = 21$; lateral Acp eyes open: $p < .41$, $df = 21$; eyes closed: $p < .90$, $df = 21$]. Similarly, no significant difference was observed with regard to COP velocity. A comparative analysis for visual dependence between eyes-open and eyes-closed conditions showed no significant difference in any of the four COP variables measured for post-TKR subjects.

Table 3. COP Root Mean Square (rms) Values of Subjects Grouped According to Ankle Plantarflexion Threshold Joint Position Sense (TJPS) Abilities

	Acp Good	Acp Poor	Vcp Good	Vcp Poor
A-P open *M*	0.74	0.94	14.70	19.30
SD	0.30	0.22	5.90	4.30
A-P closed *M*	1.00	1.84	20.00	36.90
SD	0.55	0.57	11.00	11.40
Lateral open *M*	0.82	1.16	16.40	23.14
SD	0.30	0.26	5.90	10.70
Lateral closed	1.06	2.03	21.30	40.50
SD	0.53	0.71	10.70	14.20

Notes: COP = center of pressure; A-P = anterior-posterior. COP rms values (*M* and *SD*s) of subjects with good versus poor ankle plantarflexion TJPS during eyes-open and -closed conditions. COP amplitude (Acp) and velocity (Vcp) values are in mm and mms, respectively. All good versus poor comparisons are significantly different; $p <. 05$.

DISCUSSION

The hypothesis that older adults with decreased knee or ankle TJPS would show decreased postural control was supported by this study. When asked to stand with eyes open or closed, older adults with very poor knee flexion or extension TJPS (subjects in the lower third in performance) show large root mean square A-P, and lateral COP displacement amplitudes and velocities when compared with older adults with very good knee TJPS (subjects in the upper third in performance). Subjects with very poor knee TJPS swayed even more when they closed their eyes, indicating that they depended greatly on visual feedback to maintain balance.

Table 4. COP Root Mean Square (rms) Values of Subjects Grouped According to Ankle Dorsiflexion Threshold Joint Position Sense (TJPS) Abilities

	Acp Good	Acp Poor	Vcp Good	Vcp Poor
A-P open *M*	0.78	0.94	15.60	18.80
SD	0.33	0.20	6.50	3.90
A-P closed *M*	1.20	1.69	24.63	33.70
SD	0.84	0.45	16.80	8.90
Lateral open *M*	0.86	1.15	17.20	23.00
SD	0.34	0.23	6.80	4.70
Lateral closed *M*	1.23	2.00	24.38	39.18
SD	0.74	0.71	14.50	14.10

Notes: COP = center of pressure; A-P = anterior-posterior. COP rms values (*M* and *SD*s) of subjects with good versus poor ankle dorsiflexion TJPS during eyes-open and -closed conditions. COP amplitude (Acp) and velocity (Vcp) values are in mm and mm/s, respectively. All lateral good versus poor comparisons are significantly different; $p <. 05$.

Table 5. COP Root Mean Square (rms) Values of Subjects in Extreme Ankle Plantarflexion Groups (Very Good vs Very Poor Threshold Joint Position Sense [TJPS])

	Very Good (eyes open)	Very Poor (eyes open)	Very Good (eyes closed)	Very Poor (eyes closed)
A-P Acp *M*	0.57	0.89	0.68	1.56
SD	0.06	0.13	0.10	0.38
Lateral Acp *M*	0.67	1.03	0.75	1.58
SD	0.19	0.24	0.19	0.36
A-P Vcp *M*	11.49	17.80	13.50	31.12
SD	1.12	2.60	2.00	7.54
Lateral Vcp *M*	13.30	20.60	15.02	31.60
SD	3.70	4.80	3.70	7.14

Notes: COP = center of pressure; A-P = anterior-posterior. COP rms values (*M* and *SD*s) of subjects with very good versus very poor ankle plantarflexion TJPS. COP amplitude (Acp) and COP velocity (Vcp) values are in mm and mm/s, respectively. All good versus poor comparisons are significantly different; $p < .05$.

Thus, when older adults cannot detect subtle changes in TJPS at the knee, they may be less able to maintain stability and minimize movement of the COP. This apparently leads to a reliance on vision to aid in accomplishing the task of maintaining balance.

When using less stringent criteria for poor knee extension TJPS (comparing subjects in the lower vs the upper half of the older adult group), it was found that subjects still showed increased anterior-posterior COP displacement amplitudes and velocities when eyes were open but not when closed. This was consistent with the fact that these subjects demonstrated no tendency toward visual dependence. Also, there was less effect of decreases in knee flexion TJPS than knee extension TJPS on sway during quiet stance. Essentially, a slight decrease in knee extension or flexion TJPS has little effect on posture control and appears not to have enough of an effect to cause a sensory reweighting and dependence upon vision for the maintenance of posture. However, a greater deficiency in TJPS at the knee appears to produce a more dramatic effect on the COP variance and may be a predisposing factor to the observed postural dyscontrol in the older adult population.

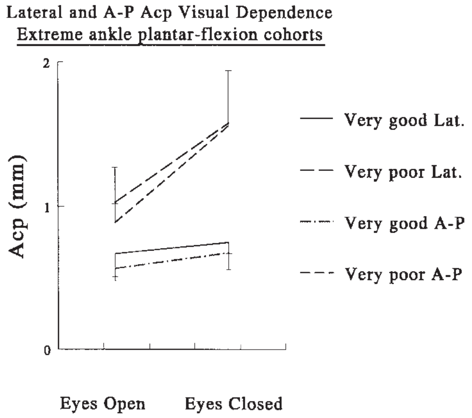

Figure 5. Visual dependence, or the increase in root mean square amplitude of center of pressure (Acp) from eyes-open to eyes-closed conditions, of subjects with very good versus very poor ankle plantar flexion threshold joint position sense. Lat = lateral; A-P = anterior-posterior.

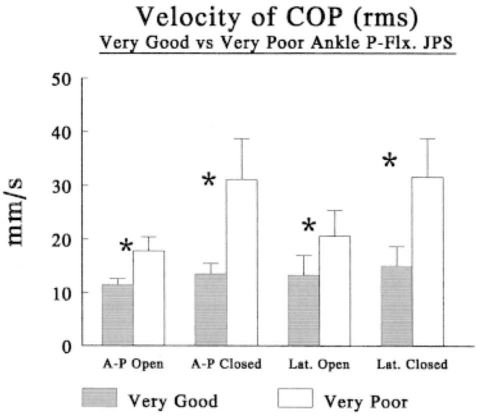

Figure 6. Velocity of center of pressure (COP; rms) in subjects with very good and very poor ankle plantar flexion threshold joint position sense (JPS). Means and standard deviations in eyes-open and eyes-closed conditions are represented. Lat = lateral; A-P = anterior-posterior; P-Flex. = plantar flexion. *$p < .05$.

Poor and very poor knee or ankle TJPS did not increase the onset latencies for automatic postural responses activated by threats to balance caused by support surface perturbations. This may be attributed to the fact that a 3.8-cm support surface displacement gives the visual and vestibular systems substantial body displacement information, and these systems may be able to compensate for any reductions in the contributions of ankle or knee proprioception to dynamic balance control in subjects with poor JPS. This may be the reason that differences were observed between subjects with very good versus very poor TJPS when evaluating the COP data, but not the automatic postural response data.

The hypothesis that TKR patients would demonstrate increased COP variance during quiet stance or increased latencies of automatic postural responses compared with the controls was not supported by this study. The amplitudes and velocities with which the two experimental groups swayed in both the A-P and lateral directions were the same. Also, postsurgical patients showed no greater tendency toward visual dependence than did controls during stance trials with eyes closed. Patients considering TKR should take this information into consideration as evidence that their balance will not be negatively affected by a TKR that renders a good result.

In conclusion, it appears that decreased TJPS at the knee or ankle may predispose older adults to postural dyscontrol in terms of COP variance during quiet stance. However, it is not apparently associated with any delayed muscle onsets of the automatic postural response to dynamic balance threats.

It is interesting that other research suggests a significant contribution of somatosensation to the triggering of the automatic postural response to dynamic threats to balance. For example, Inglis showed that in diabetic patients with peripheral sensory neuropathy, their severe somatosensory deficit produced delayed and inaccurately scaled automatic postural response onset latencies (19). This suggests that soma-

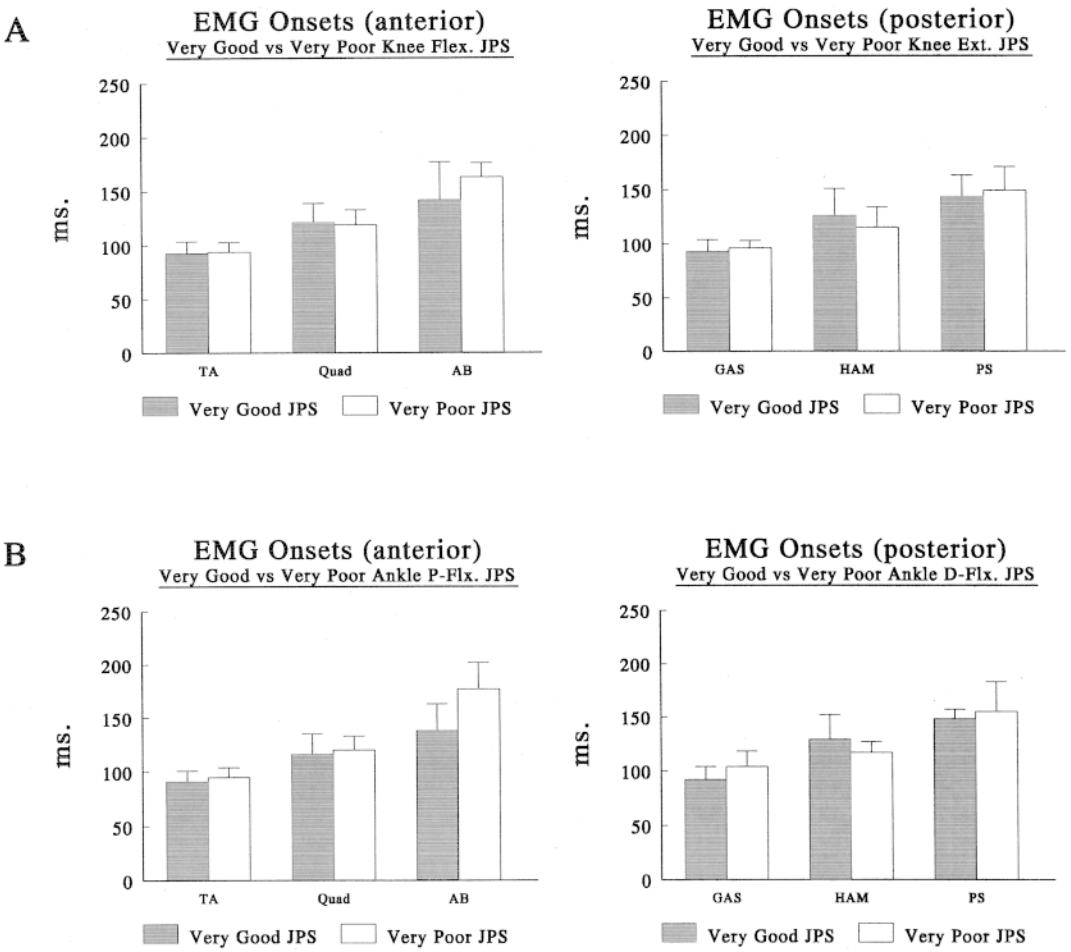

Figure 7. Electromyographic (EMG) onset latencies in response to horizontal platform perturbations for anterior (tibialis anterior [TA], quadriceps [Quad], abdominal [AB]) and posterior (gastrocnemius [GAS], hamstrings [HAM], paraspinal [PS]) muscle groups of subjects with very poor knee threshold joint position sense (JPS) (A) versus subjects with very poor ankle threshold JPS (B). No significant difference was found between groups, $p < .05$.

tosensory input is important to the task of posture control. The current study suggests, however, that a reduction in JPS, by itself, does not affect these dynamic postural responses. Thus, TJPS may not contribute as strongly to dynamic postural control as do other components of somatosensation, such as cutaneous receptors or input from rapidly stimulated muscle spindles. In addition, the observation that a decrease in TJPS was correlated to increased COP variance during quiet stance suggests that joint proprioceptive inputs contribute significantly to static balance control, with knee inputs contributing to a slightly greater degree than ankle inputs.

Because physical therapy has been shown to enhance the proprioceptive sense in patients recovering from orthopedic injuries, this is most likely an area warranting attention during the rehabilitative process of patients recovering from a lower body injury or surgery. TKR results suggest that surgeons may counsel their patients that they will likely experience no negative effect on their balance from elective joint replacement.

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