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# Formulation of Integrated Proprioceptive Screening Scale and Testing of its Sensitivity, Reliability and Validity

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**Abstract**

Proprioception is the awareness of the body position, orientation, movement and sensation of force. Proprioception is necessary to establish an accurate, efficient and coordinated response of efferent system to the demands of environment. As an evaluation is important to establish the goal of intervention in any patient, so an integrated proprioceptive assessment tool is required to examine proprioception deficit qualitatively and quantitatively. There are no evidences found, regarding an integrated approach of evaluating proprioception. In this study an integrated proprioceptive assessment scale was formulated covering all possible and related proprioceptive testing methods. The mean and SD was taken for each quantitative testing procedure documented and furthermore the test-retest reliability for each new measurement procedure was tested. The sensitivity, validity and the reliability of the scale was examined.

**Key words: Angular error, Distance error, Proprioception score, Integrated Scale, Reliability, Sensitivity, Validity**

## Introduction:

The sensory motor system covers the whole process from a sensory stimulus to muscle activation; proprioception is the process occurring along the afferent pathways of sensory motor system. (*Lephart et al, 2000*). It is the awareness of the body position, orientation, movement and sensation of force (*Sherrington, 1906*). Disturbances of somatic sensation, especially proprioception may have detrimental functional implication consequent upon poorly controlled posture and movement. Evaluation of proprioception as a part of routine neurological examination is generally qualitative in nature, and it precludes accurate and reliable identification of subtle sensory variation (*Leibowitz et al, 2008*). In order to provide most appropriate, client centered care it is most of importance to use standardized outcome measure for research and clinical practice. Unfortunately there are limited somatosensory evaluation tools (especially proprioception) with established reliability and validity available for clinical practice. The motor control and recovery are influenced by sensory impairments, the poor proprioception functioning has been shown to impact a person's rehabilitation outcomes and daily activities, also may lead to unsafe situation in the home and in social settings. It is therefore useful to assess to determine functional limitation and establish intervention goals. There are many assessments being used in clinical setting but those are lacking sufficient supporting evidence. The clinician using the conventional evaluation format should use them in combination with other

proprioception assessment to obtain most accurate measure of proprioception. *(Gandhi, 2000).*

Many of the proprioception subscale are less reliable to use and having ceiling effect and no scale which covers all aspects of proprioception assessment has been found in the literature. Most of the scales still need further research to prove reliability and validity. The grading criteria's is not discussed till now in most of the available subscales which is important to know the functional recovery and prognosis of patients. As an evaluation of proprioception is important to establish the intervention goal in any patient so a new integrated proprioceptive scale is needed to measure proprioception deficit qualitatively and quantitatively covering most of the proprioceptive domains.

## Methods

The study was done in two phases.

The first phase of the study was innovative and correlational in nature intended to formulate and integrate proprioceptive scale where the different possible techniques to assess proprioception were searched and analyzed. Then the reliability of each quantitative testing procedure was checked and final scale was formulated. Ten subjects were selected to test the reliability of the testing procedure and documentation of mean and standard deviation of the proprioceptive error (angular and distance error) in different quantitative testing procedures was done.

In the 2nd phase the sensitivity, reliability and validity of the scale was tested. The testing of sensitivity and construct validity were comparative in nature. The testing of the reliability and criterion validity were correlational in nature. The total scoring and grading using the scale was given to each subject, according to their performance in each testing procedure included in the integrated scale (IPSS). To check the intergroup sensitivity the scale was applied in different age groups and patients. To check the reliability of the scale the inter-tester and test-retest reliability was checked in 10 young aged subjects (17-25 years). The criterion validity of the scale was checked by correlating the score of the integrated proprioceptive screening scale (IPSS) to the score of Fugl-Mayer sensory subscale in 5 normal subjects (17-25 years).

*Testing equipments and procedures*

Various qualitative and quantitative testing procedures/methods were included in the form of subscales, to formulate the integrated scale. The qualitative testing procedures/subscale was as follows:

*1. Contra-lateral limb matching test:* In this the subject was shown the directions into which his or her limb was going to be moved and given full instructions about the procedure. Then he was asked to memorize the directions of movement of the moving limb thereafter do the same movement on his opposite side on contra-lateral limb within 5 seconds.

*2. Distal joint positional sense test:* The subject was asked to identify the position of the finger or toe (whether 'up, middle, or down') with closed eyes. He or she was asked to tell the right answer within 5 seconds. This test was done for all MCP and MTP joints.

*3. Perceived thumb localization test:* In this test the subject was asked, to quickly touch the index fingertip (with the

right hand) to his nose then (within 5 sec.) touch the tip of thumb (raised over head), while examiner passively places the raised arm into three different locations in space, The subject was asked to grasp or pinch the testing thumb with the other hand within 5 seconds.

*4. Perceived Synergy Sense Test:* is meant to determine the position of upper limb and lower limb (one extremity at a time) in the form of any synergy pattern. The subject was asked to assume the position, just demonstrated to him and asked him to do the position on the both sides and both limbs. If the subject was unable to duplicate the test position, the experimenter passively placed the subject's extremity into the test position and asked the subject to maintain this position. If the subject was able to assume or maintain the test position, the experimenter then asked him to hold the shoulder/hip component of the position for 5 seconds while attempting to reciprocate the most distal component of that position.

5. In multidirectional repositioning task the subject sat in a chair which was positioned as close as possible to a table. Many boxes of equal square cm over the table using chalk or micropore were made. The subject was blindfolded. The testing hand along with the coin was passively positioned by the examiner on the center box of the surface of table. The other hand was placed directly over the testing coin where it was placed in the box along with testing hand. Then during the test the examiner passively moved the testing hand from the center box to the 3 locations by gently guiding it, (target location predetermined by examiner) until the index finger of the testing (affected) hand coincided with the coin placed within the target box. The subject was asked to place his hand holding the coin within the target box. Then the subject was asked to move the contra-lateral hand towards the target direction and place the index finger directly near to his/her perceived location of the testing index finger over the coin placed within target box. When the subject had completed the movement the examiner marked the position of the index fingers and then the target was shifted to the next testing location. The displacement of the contra-lateral index finger from the coin (target location) was determined.

The quantitative testing procedures were,

*1. Foot Placement Sense Test:* The subject was instructed to walk on 12 feet long paper with comfortable foot step. He was told to memorize the placing of his each foot step. Then with eyes fixed to a point in front or not looking down, he was told to walk on the same paper roll as before for once. Then the error was recorded by comparing between the taken target footprint and subject's original foot placement with visual fixation after walking. The average of the error was taken and grading was done as according to the performance of the test.

*2. Objective Positional Sense Test:* The subject was asked to move his testing limb to the predetermined target angle/position and let him feel that angle/position for 5 sec. Then the limb was taken to the starting position passively, the subject was then asked to move the limb to that target position actively from the starting position. The angular difference between the target angle and patient's perceived angle was measured. The angular error in each plane of a joint was recorded and was taken as

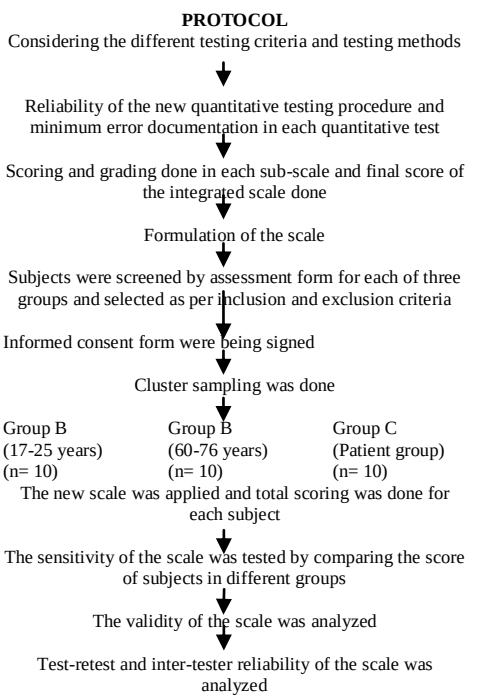
the actual angular error in one particular plane of a joint.

3. *Timed up and go test:* A 3 meters or 10 feet distance using tape was marked, the subject was informed about the test sequence and outcome. The subject was instructed to stand up from the chair walk to the mark on the floor, turn around, walk back to the chair and sit down. Timing was recorded using stop a watch.

4. *Motion tracking sense test:* This is an instrument designed to measure the proprioceptive error in an individual quantitatively. This instrument is made up of wood and has a slider to point out the reading on the scale and protractor fixed on the instrument. The subject was seated in front of a table on which the instrument was kept. The Subject was asked to slide the pointer in the instrument to a predetermined number on the scale over the instrument with opened eyes and maintain for 5 seconds there, so that the subject could memorize the position. Then with vision blocked the subject was asked to reposition in the target position. The distance and angular error in between the target angle/distance and subject's perceived distance/angle respectively were recorded.

5. *Modified Romberg test:* In this test the subject was asked to close his eyes and stand on one leg for one minute and the number of times the subject lost balance in one minute was recorded.

6. *Timed Unilateral Stance Performance test:* Subject was asked to stand comfortably and fix his eyes further to a point. Thereafter the subject was asked to stand on the right and left foot separately as long as possible without losing balance or fall. The time duration he could stand without losing balance was recorded.




# Results:

**Table 1: Reliability of the FPST-foot placement sense test (r value in between attempts)**

| FPST A Rt. SIDE | 1 Vs 2 | 1 Vs 3 | 2 Vs 3 |
|---|---|---|---|
| | r value | r value | r value |
| Rt. Foot Dist. Error | 0.96* | 0.87* | 0.80* |
| Lt. Foot Dist. Error | 0.86* | 0.78* | 0.95* |

*** P< 0.05**

This table shows the r values between three attempts done in both two variables. There is highly significant correlation in between attempts taken on right and as well as left side foot. The r values in between three attempts were >0.80 and p values were <0.05 which shows the test was significant.

**Table 2: Reliability of the MTST-Motion tracking sense test on right side upper limb**

| MTST RT. SIDE | 1 Vs 2 | 1 Vs 3 | 2 Vs 3 |
|---|---|---|---|
| | r value | r value | r value |
| SAGITTAL | 0.89* | 0.88* | 0.77* |
| TRANSVERSE | 0.78* | 0.82* | 0.78* |
| ANGULAR | 0.82* | 0.80* | 0.86* |

* **P< 0.05**

This table shows the r value in between three attempts done in all three variables. There is highly significant correlation in between attempts taken saggital, transverse, angular error measurement in MTST on right side. The r value for all were >0.77 and p values were <0.05. These shows the testing procedure was significant to test proprioception.

**Table 3: Reliability of the MTST-Motion tracking sense test on right side upper limb**

| (VARIABLE) MTST Lt. Side | 1 Vs 2 | 1 Vs 3 | 2 Vs 3 |
|---|---|---|---|
| | r value | r value | r value |
| SAGITTAL | 0.94* | 0.75* | 0.80* |
| TRANSVERSE | 0.72* | 0.76* | 0.86* |
| ANGULAR | 0.88* | 0.77* | 0.77* |

This table shows the r value in between three attempts done in all three variables. There is highly significant correlation in between attempts taken saggital, transverse, angular error measurement in MMTT on left side. R values were >0.75 and p values were <0.05 for all showing the testing procedure was significant.

**Table 4: Mean and SD of proprioception score (%) in young (A), elderly (B) and patient (C) group obtained by IPSS**

| Variables | GROUP A | | GROUP B | | GROUP C | |
|---|---|---|---|---|---|---|
| | Mean | ±SD | Mean | ±SD | Mean | ±SD |
| Age | 22.60 | 2.54 | 65.70 | 3.65 | 43.70 | 14.53 |
| Prop. Score | 97.42% | 0.75 | 91.79% | 2.93 | 79.38% | 13.56 |

The table shows the Mean and Standard Deviation scores for Proprioception score (%) in different groups (A, B, C). The mean and SD in group A were 97.42% and ±22.6, in group B 91.79% and ±2.93, in group C 79,38% and ±13.56.

**Table 5**: **Inter-group sensitivity of IPSS**

| VARIABLE | GROUP A Vs B | | GROUP A Vs C | |
|---|---|---|---|---|
| | U value | P value | U value | P value |
| PROP. SCORE | -3.788 | P< 0.05 | -3.785 | P< 0.05 |

This table describes the difference of the scores of proprioception (%) by **Mann Whitney U test** in group A Vs B, B Vs C, C Vs A which shows the proprioception score (%) is significantly different in Group A Vs group B, Group A Vs Group C ($p < 0.05$).

| VARIABLE | Group A Vs B Vs C | |
|---|---|---|
| | $\chi 2$ value | P value |
| Prop. Score | 20.812 | **P < 0.05** |

This table describes the difference of proprioceptive scores (%) in between three groups (A, B, and C) by **Kruskal-Wallis test**, which shows the proprioception score (%) is significantly different in between three groups. The level of significance was high (p value <0.05).

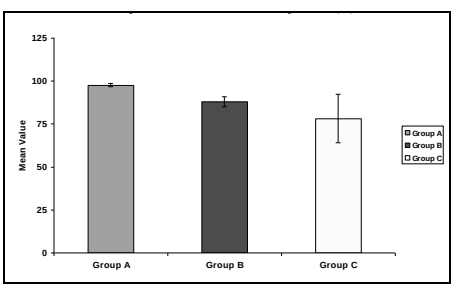



**Figure 1 : Comparison of mean Prop. Score**

**Table 6: Test-retest reliability of IPSS**

| VARIABLES | Mean | ±SD | R value | P value |
|---|---|---|---|---|
| PERCENT ME | 97.42 | 0.75 | 0.84 | <0.05 |
| PERCENT ME2 | 97.88 | 0.62 | | Sig. |

This table shows the test-retest reliability done by **ICC**, which describes that the scale having high test-retest reliability. The test-retest reliability was 0.84, which was highly significant.

**Table 7: Inter-tester reliability of IPSS**

| VARIABLES | Mean | ±SD | R value | P value |
|---|---|---|---|---|
| PERCENT ME | 97.42% | 0.75 | 0.843 | <0.05 Sig. |
| PERCENT PT 1 | 96.89% | 1.18 | | |

This table shows the inter-tester reliability done by **ICC**, which describes that the scale having high inter-tester reliability. The inter-tester reliability was 0.84, which was highly significant.

**Table 8: Inter-tester reliability by ICC**

| VARIABLES | Mean | ±SD | R value | P value |
|---|---|---|---|---|
| PERCENT ME | 97.42% | 0.75 | 0.854 | <0.05 |
| PERCENT PT2 | 97.61% | 0.64 | | Sig. |

This table shows the inter-tester reliability done by **ICC**, which describes that the scale having high inter-tester reliability. The inter-tester reliability was 0.85, which was highly significant.

**Table 9: Inter-tester reliability by ICC**

| VARIABLES | Mean | ±SD | R value | P value |
|---|---|---|---|---|
| PERCENT PT1 | 96.89% | 1.18 | 0.730 | <0.05 |
| PERCENT PT2 | 97.61% | 0.64 | | Sig. |

This table shows the inter-tester reliability done by **ICC**, which describes that the scale having high inter-tester reliability. The inter-tester reliability was 0.73, which was significant.

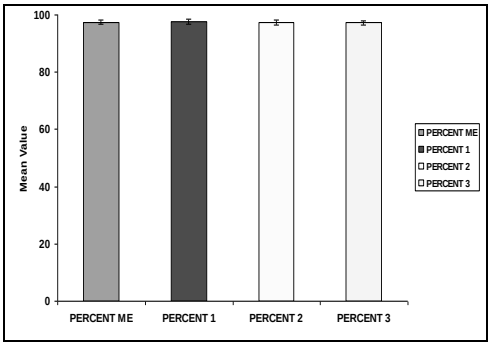



**Figure 2: Mean comparison of percent scores**

Fig 2 shows the test-retest and inter-tester reliability of the integrated proprioceptive screening scale.

**Table 10: Construct validity of IPSS**

| GROUP A Vs B | |
|---|---|
| Test statistics T | P value |
| 155 | **P < 0.05** |

This table shows the difference of proprioception acuity (mean proprioceptive score) in between two age groups by Mann Whitney test where statistics T value was 40 and difference of the mean score in between two age groups was highly significant ($p < 0.05$).

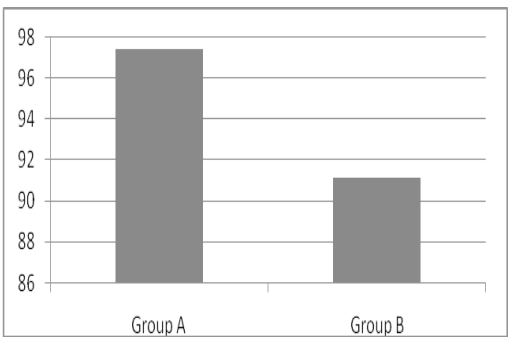



**Figure 3: Comparison of construct validity of the integrated scale between the two age groups**

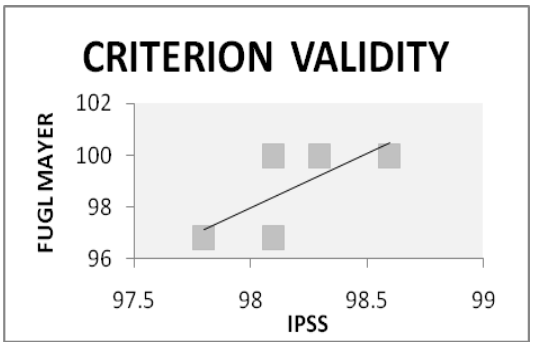



**Figure 4: Criterion validity of IPSS by correlation of the proprioception score with Fugl-Mayer sensory sub-scale**

**Table 11: Criterion validity of IPSS**

| IPSS VS FUGL-MR | |
|---|---|
| R value | P value |
| 0.71 | **P > 0.05** |

Table 11 & Fig 4 shows the correlation of proprioception score obtained by IPSS and Fugl Mayer on same subjects. The r value was 0.71.

**Discussion:**

Reliability of all of the quantitative procedures in this study was done before including the procedure within the integrated scale. The mean and standard deviation or proprioceptive error in normal healthy subjects was documented for further use as a reference to form the grading criteria in each subtest. The mean and standard deviation is mentioned below while discussing each subscales. This will help to make the sub-scales more reliable to examine proprioception and extent of proprioceptive deficit. All these tests and reliability made the scale more quantitative and qualitative.

Qualitative tests: Contralateral limb matching test is supported by Brunstrom S. who has mentioned the duplication of the joint position and direction to test the proprioception in his book "Movement therapy in hemiplegia". This test was done on all four extremities for shoulder, elbow, wrist, hip, knee and ankle joints. The thumb localization test was used by *Redding and Potes (1988*) who assessed upper limb position sense using a task in which the person was required to locate their thumb, blindfolded. For perception of joint synergy test, *Leo and Soderberg (1981)* have correlated the perception of joint synergy and joint position sense. In multidirectional repositioning task, Feedback from the muscle, tendon, joint and cutaneous receptor provides proprioceptive information regarding changes in the joint position and the muscle force. Muscle spindle information codes for both static and dynamic aspects of limb displacement which is important for goal directed movement, such information is critical in limb joint timing during multi joint movement *(Bevan, Cordo 1994, Diane E Adamo 2007)*

Quantitative tests: For foot placement sense test *Riskowski et al (2005)* has concluded that the proprioception acuity is related to gait kinematics during walking. Here in our study we have used the half of the step width during gait. For motion tracking sense test *Leibowitz et al (2008)* who stated in "Automated measurement of proprioception of upper limb" the cerebral processing of the hand position in space is based on the integration of the signals arriving actually from upper limb joints. In objective positional sense test by Paillard and Branchon who found that with passive re-positioning the error in matching the position of the outstretched arm is average 2 degree. Hurley et al in his study has found that there is a

correlation between the proprioception acuity and postural stability and he used monopedal stance time to check for the postural stability without losing balance. Muscle strength proprioception acuity and postural control contribute to mobility and confidence, enhancing the performance of common functional ADLs *(Hurley and Joanne 1998).*

**Sensitivity, reliability, and validity:**

There was significant difference between the three groups ($\chi$**2**value = 20.812). The scores were highly different in between the different age group and patients. The intergroup sensitivity was statistically significant. This result is supported by the study of Hurley MV et **al** who stated that muscle strength, proprioception acuity, and postural stability contributes to mobility and confidence, these parameters deteriorated with age. Age related proprioception impairment is a generalized phenomenon not related to specific aspect of motor performance *(Adamo et al)*. This result is supported by *Riberio et al (2007)* who found the evidence of proprioceptive deterioration with aging. *Darling et al (2004)* stated that, lesion in the parietal lobe causes the decrease in the kinesthesia in affected arm. *Leibowitz et al (2008)* found in his study that the distance and directional error was more in case of stroke patients in compared to control group subjects. The test-retest reliability of the scale is 0.80 to 0.84 and which statistically found to be significant. The inter-tester reliability of the scale is 0.83, 0.81, 0.82, and 0.81. This describe the scale is having statistically significant reliability. The criterion validity of the scale was checked by correlating the scores of the IPSS and fugl-Mayer. The correlation was significant (r value 0.71). The mean score of IPSS was 98.18% (±0.29), whereas the mean score of the Fugl Mayer was 98.72% (±1.75). This shows that the scale (IPSS) is having adequate validity. The construct validity of the integrated scale, was examined by applying the scale in different age groups. The difference of score between group A and group B was significant (test statistics T = 155, p value <0.05). The scores were highly different in between the different age groups (elderly and adolescent age group). This shows that the scale distinguishes the proprioception between the different groups of subject. This result was supported by *Adamo et al (2007)* who found greater matching error, more prolonged and irregular timed movement in case of elderly age group in compared to young adult age group, he also has mentioned the importance of inter-hemispheric transfer and retrieval of memory based proprioceptive information which needs the cognitive processing during complex sensory motor task.

In the end we can conclude that, the newly formulated proprioceptive screening scale was formed which is an integrated screening scale and it is also a sensitive, valid and reliable scale for measuring proprioception and proprioceptive deficit.

## Conclusion

The newly formulated scale is an integrated, qualitative and quantitative scale which is a sensitive, valid and reliable tool to measure proprioception.

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