Acta Scientific Neurology (ISSN: 2582-1121)

Volume 7 Issue 2 February 2024

Research Article

Better aggregation of Pain scores and Quality of Life

Chakrabartty Satyendra Nath*

Indian Statistical Institute, Indian Maritime University, Indian Ports Association, India

***Corresponding Author:** Chakrabartty Satyendra Nath, Indian Statistical Institute, Indian Maritime University, Indian Ports Association, India

Received: November 01, 2023

Published: January 16, 2024

© All rights are reserved by **Chakrabartty Satyendra Nath.**

Abstract

Background: Assessment of pain intensity, factors of pain after surgery and their effects on Quality of Life (QoL) by tools using Likert items or Numerical rating scales, etc. are not comparable and may give different results. No instrument performed uniformly as "best" or "worst".

Method: A method of transforming raw scores to normally distributed scores (P-scores) is described. Based on proposed P-scores, the paper proposes, an overall pain status (OPS) by arithmetic aggregation of component variables. Similarly, P-scores of items of QoL are combined to get overall QoL scores (QoL_{Total}). Empirical relationship can be established between OPS and QoL_{Total} to predict the later with knowledge of the former. In addition, ratios of P-scores of each factor, measure of pain intensity and QoL at the current period and the base period may be combined by multiplicative aggregation to find composites index of overall pain status (*OPSI*) by $OPSI = (P_{1c}.P_{2c}.....P_{nc})/(P_{10}.P_{20}..... P_{n0}) *100$

Results: Scores of OPS and QoL_{Total} are monotonic following normal distributions meaningful comparisons and classification of patients and assessing progress/deterioration of a patient or a group of patients and drawing path of improvement/decline. Cut-off scores of different scales can be integrated by considering equivalent scores (x_0 y_0) of two scales. In addition, P-scores help to find reliability as per theoretical definition and factorial validity to reflect validity of the main factor for which the scale was developed. For the index *OPSI*, aggregation of dimensions = *OPSI* as aggregation of components variables giving minimum trade-off among the dimensions or components. Dimensions or components where P_{ic}/P_{i0} <0 are critical requiring attention of the physicians and care givers.

Conclusions: Proposed method of transforming ordinal scores of K-point items to continuous, monotonic scores following normal distribution helps to avoid major limitations of existing summative scores and facilitate undertaking analysis under parametric set up. From the angle of distribution, OPS may be preferred than *OPSI*. Future studies with multi-data sets involving more than one QoL scales are suggested to investigate characteristics of OPS and index of overall pain status (*OPSI*) along with clinically relevant issues and psychometric properties of the proposed transformations.

Keywords: Pain Intensity; Quality of Life; Normal Distribution; Responsiveness; Equivalent Scores; Reliability; Validity

Introduction

Pains may be classified on the basis of pain conditions and peripheral locations like **back pain, neck pain, headaches, shoulder, knee pain, etc. or central sensations like** spinal and supraspinal or by types of pain like

- Acute pain (caused by a specific injury or event, surgery, bone injury, cuts or burns, dental problems, labor and childbirth, etc.);
- **Chronic pain or long lasting pain resulting from** health conditions like cancer, fibromyalgia, circulation problems, back pain, etc. and refer to more than one disorders;
- **Neuropathic Pain arising out of** damage to nerve or other parts of the nervous system.
- Nociceptive pain due to tissue damage often caused by an external injury.
- Neuroplastic pain resulting from the brain misinterpreting messages from the body as if they were dangerous and makes the brain and nervous system super-sensitive and hyperactive to otherwise normal sensations and activities.
- Radicular pain when spinal nerve gets compressed or inflamed and radiates from the back and hip into the leg(s).
- Psychogenic pain having physical/psychological origin but lasts longer due to anxiety, fear, depression, stress, etc. and may be caused by psychiatric disorders.

Multidimensional aspects of pain are Sensory (Intensity, location, character of the pain sensation), Affective (Emotional and perceived components) and Impact (Disability or dysfunctions) – all affecting quality of life (QoL).

Physical therapy is often resorted to mitigate acute and long-term pain affecting day-to-day functions and even mental health. Techniques used by Physical therapists include among others:

- **Low-impact aerobic** workouts to rev up heart rate and still take it easy on joints. For example, instead of walking or running fast, one may use a stationary bike to warm up, before starting s**tretching** or other strengthening exercises.
- **Pain relief exercises focusing on** target areas with pain.
- **Heat and ice packs to** warm up muscles for better movement or to calm inflammation.
- **Massage** on soft tissues in target areas.
- Transcutaneous electrical nerve stimulation (TENS) where a **low**-voltage electric current is sent to the skin over the area having pain.
- Ultrasound sends sound waves to the areas that hurt. Both TENS and sound waves provide relief by blocking the pain messages to brain.

Persistent post-surgical pain (PPSP) or chronic post-surgical pain (CPSP) refers to persistent pain following surgery resulting in reduced QoL. As per the standardized definition of CPSP in the International Classification of Diseases, Eleventh Revision (ICD-11) [1], CPSP covers:

- Pain developed or increased in intensity after surgery or tissue injury.
- Pain persisting beyond the healing process (3 months) from the triggering event.
- At the surgical/area of injury or projected onto the innervation area of nerves in this area or related to a dermatome or Head's zone (after surgery or injury to deep somatic and visceral tissue) and excludes pain due to other factors like infection, malignancy, etc. [2]. Illustrative clinical symptoms of patients with CPSP due to the central sensitisation processes are hyperalgesia (increased painful sensation due to noxious stimulus), allodynia (painful sensation due to non-painful stimulus), dysaesthesia (unpleasant touch perception or tingling) indicating nerve damage and central sensitisation very early after surgery [3]. Changes in some of these symptoms can be assessed by using quantitative sensory testing (QST). Early detection of post-surgery Hyperalgesia helps to predict prolonged, chronic neuropathic pain resulting in intense pain, limitations in daily activities affecting QoL [4]. Other symptoms like Visceral pain (pain from the internal thoracic, pelvic, or abdominal organs), inflammatory and neuroplastic pain due to surgery of knee, hip, abdominal, etc. may be less associated with neuropathic CPSP [5].

Identification of risk factors helps to decide strategies for preventative treatments and use such factors in predictive models. Major risk factors are

- Surgical risk factors: Acute post-operative pain, chronic pain like fibromyalgia, migraine, low back pain, etc. increase the risk of CPSP. Moreover, coexisting psychosocial risk factors, comorbidities and long-term use of opioids, etc. contribute to high incidence of CPSP.

- Psychosocial risk factors: Psychological distress, anxiety, catastrophising, lower ability to cope with pain, depression and hyper vigilance, etc. tend to increase CPSP risk. Anxiety is the main psychological risk factor for CPSP followed by depression, catastrophising, kinesiophobia and impaired self-efficacy [6].
- Patient-related risk factors: Include age, female sex, high BMI etc. which are positively related with increased risk. Similarly, education level and socioeconomic factors have also been identified as risk factors. Varying degree of association of such factors with acute and chronic post-operative pain has been observed [7,8].

Risk factors for CPSP are not independent of each other. For example pre-operative pain is more common in females and psychological disorders are related to higher sensitivity to experimental pain as well as to pre-operative chronic pain [6,9]. However, risk factors vary with different types of surgery.

It could be desirable to combine all the risk factors, measures of pain intensity and QoL to form a composite index, reflecting overall pain status (OPSI) following methodologically sound procedure enabling meaningful ranking of patients along with identification of relative importance of each component measure for further necessary actions. Alternatively, attempts can be made to aggregate chosen measures of pain qualities and finds its relationship with QoL measures to predict to later with knowledge of the former.

The paper gives a method of transforming raw scores to normally distributed scores for meaningful arithmetic aggregation leading to meaningful comparisons of patients in terms of combined pain qualities (CPQ) across time and space.

Literature survey

Effectiveness of physiotherapy management was reviewed [10] and observed that physiotherapy could contribute in management of CPSP. Tools developed to assess risk of patients following surgeries of different types, illustrative list is as follows

- Breast cancer surgery: Four risk factors viz. pre-operative pain in operative area, high BMI, auxiliary lymph node dissection, higher post-operative pain intensity on the 7th day were considered [11]. However, pre-operative screening is not possible
- Mixed surgical cohort (Orthopedic surgery, general surgery, visceral surgery, neuro-surgery): Risk factors are pre-operative pain in the operating field, other pre-operative pain, post-operative acute pain after 5-days, capacity overload, comorbid stress symptoms [12].
- Inguinal hernia repair, Hysterectomy (vaginal or abdominal) and Thoracotomy: Risk factors like Age, Surgical procedure, Physical health and Mental health (both assessed by Short Form Health Survey-12(SF-12), Pre-operative pain in the surgical area and in another areas – were considered [13] allowing pre-operative screening.

Qualities are reported in terms of sensitivity, specificity, discriminative value as receiver operating curve (ROC) and area under the curve (AUC). However, traditional ROC-AUC approach assumes normal distribution and is used primarily for binary classification at various cut-off values i.e. for diagnosis purpose. Higher value of AUC reflects that the model is good in distinguishing patients with or without the disease in question and not for combining measures of factors of pain per se.

ROC-AUC analyses are not without limitations. Cut-off points get affected by sample characteristics, among others. Comparison of cut-off points from different studies is not possible [14]. For Cancer Core Questionnaire(EORTC QLQ-C30) [15] found four cut-off scores for different treatment status. In addition, Odd ratio and Relative risk fail if the assumption of independence is violated. For small sample size, ROC curve is jagged, but tends towards a smooth curve as the sample size gets increased [16] $AUC_{Test\text{-}1} = AUC_{Test\text{-}2}$, may not imply identical ROC curves for the two tests. Two ROC curves may even cross each other.

According to [2], major problem areas are methodological differences arising from different methods of data collection and definitions of CPSP variables, small sample size, limited surgical procedures, methodological deficiencies in most Randomized controlled trials(RCTs), arbitrary selection of QoL tools, etc. The authors made several suggestions like replacing SF-12 by Patient Health Questionnaire (PHQ-9) or General Anxiety Disorder (GAD-7); consideration of longer treatment durations in sample of patients only who are at risk, subgroups of patients and prediction of acute/chronic post-operation pain based on somatosensory profile of patients before surgery by using QST towards prevention of CPSP and adaptation of multidisciplinary approach, including non-pharmaceutical therapies like physiotherapy and appropriate psychological supports.

Scales to assess Pain

Commonly used tools for assessment of postoperative pain intensity among adults are one-dimensional like:

Visual Analogue Scale (VAS): Subjects mark part of 100-mm straight line to denote their pain severity [17]. VAS-scores by vertical or horizontal lines differ. Vertical scale showed less error than the horizontal scale for Chinese patients [18]. VAS-scores with poor sensitivity can be misunderstood [19]. VAS fails to detect small changes in pain. Patients undergoing extensive surgery tended to endorse higher VAS-scores i.e. higher pain intensity. VAS-scores 33 is acceptable pain control, after surgery [20]. Change in pain by VAS-scores is non-linear. For example, reduction of VAS from 90 to 70 reflects greater relief in comparison to reduction of 30 to 10.

Numerical Rating Scale (NRS): Two extreme points 'no pain" and "worst pain" are presented in 11-point or 21-point or 101-point scale [21]. For 101-point scale, subjects may tend to choose values in multiples of five. Interpretations of a particular pain score vary for NRS-11and NRS-101. Researchers differed in deciding anchor values and also Minimal Clinically Important Difference (MCID) of NRS. Sensitivity of NRS differed at different scale points [22]. Summative NRS score is taken as proportional to pain intensity. Statistically significant changes in VAS or NRS may not result in changes which are clinically important.

Verbal Rating Scale (VRS) or verbal descriptor scale (VDS): Subjects to choose each of the given adjective under "no pain"; "mild pain"; "moderate pain"; and "severe or intense pain" which fits best to the pain intensity [23]. VRS may lead to misapprehension that intervals between a successive pair of adjectives are equal and thus induce error [24]. Out of 15 adjectives in a VRS, patients used only six of them and 4 of the 6 adjectives covered 78% of responses [25].

However, such unidimensional tools are inadequate to measure pain. The respective cut-off points do not reflect the patient's desire for additional analgesics [26]. Moreover, difficulties are faced by patients in describing their pain experience by a single numerical value, descriptive words, or marking on a line [27]. Treating pain as the fifth vital sign is not encouraged as it might have contributed to the opioid epidemic [28]. After surgery, error rate was very high for VAS and not preferred over NRS-11 and no unidimensional instrument showed adequate measurement properties in assessing postoperative pain [29]. In addition, pain management needs consideration of many dimensions of pain experience and not solely by cut-off points of unidimensional tools [30].

Hence, the need of multi-dimensional tools in assessing and managing post-operative pain. Frequently used multidimensional pain assessment tools are

- **McGill Pain Questionnaire (MPQ):** Measures pain intensity, along with physical and emotional characteristics of pain. Here, 20 subgroups of words describing 4 dimensions are given viz. sensory-discriminative (subgroup 1-10; score range 0 - 42), motivational–affective (11-15; score range 0 - 14), cognitive-evaluative (16; score range 0 - 5), and miscellaneous components of pain (17–20). Each subgroup contains a list of words with a given ranking. Pain Rating Index (PRI) is the sum of ranked scores and Present Pain Intensity (PPI) is assessed on a six-point scale (i.e. pain from 0 to 5 [31]. However, different number of items and different score ranges in the subcategories yields different contributions to the dimensions. Aggregation of scores of dimensions and miscellaneous items by summative score to get PRI fails to satisfy many desired properties of measurement. Moreover, three pain patterns of MPQ are not adequate to account for changes in pain experienced by participants [32].
- **Brief Pain Inventory (BPI):** 17-item scale includes sensory and reactive dimensions, which measures both pain intensity and the interference of pain with activities of daily living [33].
- Here, a patient indicates the site(s) of his/her pain by shading a body diagram. To assess the pain intensity during the previous 24 hours, it uses NRS-11 consisting of seven dimensions of usual activities/functions and mood (e.g. work, sleep, mood, relations with other people). Thus, BPI assesses pain experience of patients through a number of different scales. Aggregation is done ignoring inter-relationships among those scales, distribution of scores for each scale and thus, properties being satisfied by the chosen aggregation method are not known.
- **Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) pain scale:** Measures autonomic changes based on analysis of sensory descriptions and bedside examination of sensory dysfunctions with seven items. Subjects indicate presence (scores are 1, 2, 3 and 5 for different items) or absence (zero scores) of dysfunctions which are summed to get the scale scores (maximum 24) and 12 is taken as the cut-off value.
- **Surgical Pain Scales (SPS):** With 4 items (NRS-11), it measure pain at rest, during normal activities, during work/exer-

cise and quantify extent of unpleasantness of worst pain i.e. both the sensory and affective components of postoperative pain [34]. Validity of SPS was found as correlations with relevant dimensions of SF-36. Limitations of SPS are similar to same for NRS-11.

- **Pain Assessment in Advanced Dementia scale (PAINAD):** Includes breathing independent of vocalization, negative vocalization, facial expression, body language, and consolability. For each specific pain behavior, scores ranges from 0 – 2 and scale score of 1-3 indicates mild pain, 4-6: moderate pain and 7-10: severe pain. However, interpretations of behaviours in PAINAD is complex due to considerable overlap between behavioural symptoms of dementia and behavioural symptoms of pain, and thus, raises concerns about validity of PAINAD [35]. In addition, people with advanced dementia cannot use PRO scales which demands verbal and cognitive skills [36].
- **Douleur Neuropathique 4 questions (DN4):** Yes – No type items where "Yes" response is scored as 1. Maximum possible score is 10. A score 4 is taken as neuropathic pain.
- **Pain DETECT questionnaire (PD-Q):** Seven number of 6-point items (0 to 5) for quality of neuropathic pain symptoms plus one item on Pain course pattern and one more item on Radiating pain.
- **Neuropathic Pain Score (NPS):** To assess qualities of pain associated with neuropathic pain based on 11 descriptors. However, NPS includes a heterogeneous group of etiologically different diseases from cancer to diabetes. Thus, a single cut-off score for NPS may not be valid for all diseases. It has good sensitivity to treatment effect.

However, there is no basis to select the most reliable and valid tool covering only the dimensions relevant to pain in postoperative adult patients.

QoL tools

Various multidimensional generic and disease-specific QoL tools have been used covering dimensions like physical, functional, social, and emotional well-being of patients after surgery [37]. For patients undergoing lumbar discectomy, [38] used SF-36 and Oswestry Disability Index (www.orthosurg.org.uk/disabilityindex). But, SF-36 does not provide total scores and instead compute physical component summary (PCS) scores and mental component summary (MCS) scores. Based on changes in SF-12 [39], before and after surgery, it was found that major surgery decreases postoperative PCS-scores [40]. For assessment of clinical outcomes after cervical spine surgery [41], used Odom's criteria scale. Assessment of quality of pain management is best done by patient-reported outcome measures (PROMs) [42]. Comparison of four health-status measures: *NHP*, *SF-36*, *COOP/WONCA* charts, *EQ-5D-5L* found that no instrument performed uniformly as "best" or "worst" [43]. Selection of QoL instrument depends on health dimensions relevant to the set of patients and also psychometric qualities of the instruments.

In addition, specific questionnaires to assess disabilities and psychological factors were used like Depression Scale, modified somatic perception questionnaire (MSPQ) to study effect of depression and somatic anxiety, World Health Organization Disability Assessment Schedule (WHODAS), etc. Patient–reported scales are often skewed, with floor or ceiling effects, and normality checks are necessitated for inferences [44]. Discrete ordinal data are not normally distributed; violets assumptions of many statistical procedures [45] and parametric statistical analysis are problematic [46]. A scale must have the following features: metric, presence of zero point, and clearly defined operational procedure as the basis for measurement [47].

Limitations of scales as measurement tools

Barring VAS, the above mentioned scales use Likert scale or NRS with different number of items and response options. Scoring methods of the scales suffer from methodological limitations, in terms of meaningful aggregation of item or dimension scores following different and unknown distributions and not satisfying the basic assumption of normality for statistical analysis like Principal component analysis (PCA), Factor analysis (FA), Analysis of variance (ANOVA), goodness of fitting regression equation, *t*-test, *F*-test, etc. Comparison of Scale- A and Scale-B may go beyond finding average score in each scale or finding association between the scales. Scale with higher number of items and higher number of response-categories has higher mean, Standard deviation (SD), reliability and validity [48]. Better is to find whether proportion of persons with a particular score in Scale-A and Scale-B are equal or not. In other words, we are talking of probability distributions of scores emerging from Scale-A and Scale-B. Similar distribution of Scale-A and Scale-B scores (say normal distribution) will help to have meaningful arithmetic aggregation of item scores and statistical testing like equality of mean of the two scales, etc.

Tools to assess disabilities, psychological factors and QoL tools usually use summative scores of ordinal responses to K –point items where K= 3, 4, 5, 6, … or combination of items with different values of K including binary items (K=2). However, dimensions covered, numbers of items (scale length), width of items (number of response-categories), scoring methods, distributions of test scores, etc. are different for different instruments and can influence areas like treatment effect, patient care, policy issues, etc.

Consideration of zero as an anchor value:

Zero as an anchor value indicating "no pain" can change mean, SD, skew, kurtosis of the scales and implies mean = variance = 0 for the "no pain" sub-group and creates difficulties in computation of between group variance. For multi-item scales, large number of zero responses to an item lowers the covariance and correlation with that item. Expected values of level-wise score are not meaningful if zero is attached to a level.

Nature of data

Generated data are ordinal and discrete. Summative scores assume

- Items are of equal importance, despite different values of inter-item correlations, item-total correlations and factor loadings.
- Distance between No pain and Mild pain (d_{12}= distance between Moderate pain and Mild pain (d_{23} = distance between Severe and Moderate pain (d_{24}) and also a rating of 10 is equal to twice as much pain as a rating of five. Verification of equidistant property is not done by scale scores.

Aggregation procedures

Scales generating ordinal data do not consider distribution of scores. Interpretation of $X \pm Y$ is difficult when item scores follow unknown and different distributions. Addition of two random variables $X + Y = Z$ is most meaningful if P(Z=z)=P (X= x, Y= z - x) for for discrete case and P(Z ≤ z)=P (X+Y ≤ z)= $\int_{-\infty}^{\infty}(\int_{-\infty}^{z} f_{X,Y}(x, t-x)dt)\ dx$ for continuous case. Thus, it is necessary to know probability density function (pdf) of X and Y and their convolution.

Thus, arithmetic aggregation of item scores is not meaningful. Summative scores suffer from compensatory approach, where a low score of a dimension can be compensated by high score in another dimension.

- **Normalization of raw data:** Different score-ranges of item scores (like MPQ) are often normalized to have uniform score range for all items. However, different methods of normalizing result in change in shape of distributions in different fashions and may influence the final pain scores.
- **Proposed method**
- **Pre –adjustment of data**
    - Ensure that each item is positively related to Pain intensity i.e. higher the score in the item, higher is pain intensity which in turn indicates lowering QoL
    - Assign 1, 2, 3, 4, 5, etc. to the response-categories of items avoiding zero.

A method to obtain equidistant scores of items (E_i-scores) in ratio scale was given [49] where ordinal scores of i-th item is transformed to continuous scores by weighted sum based on weights considering frequencies of response-categories of items and E_i-scores were further transformed to proposed scores (P_i-scores) following normal distribution where $1 \le P_i \le 100$. Score of j-th dimension (D_j) is taken as sum of P_{is} for the items related to the dimension. Scale score is equal to $\sum_j D_j = \sum_i P_i$. Clearly, dimension scores and scale scores follow normal distributions and parameters of the distributions can be estimated from data.

Normally distributed scale scores for each scale to assess pain and associated factors can be added to get overall pain status (OPS) and separately for the dimensions of QoL to get overall QoL scores (QoL_{Total}). Distribution of each of OPS and QoL_{Total} will be normal. Empirical relationship can be established between OPS and QoL_{Total} to predict the later with knowledge of the former.

In addition, proposed scores of each risk factor, measure of pain intensity and QoL for the current period and separately for the base period (say time of diagnosis) may be computed and their ratios can be combined by multiplicative aggregation to find composites index of overall pain status ($OPSI$) by $OPSI = \frac{P_{1c}.P_{2c}.....P_{nc}}{P_{10}.P_{20}.....P_{n0}} * 100$ i.e. ignoring the n-th root of geometric mean of the ratios. $OPSI$ reflects overall improvement/decline in the current period from the base period by a continuous variable. However, $OPSI$ may be computed separately for male and female, high BMI and low BMI etc. to see behavior of the index over various patient-related risk factors and

to make findings clinically relevant. It is known that ratio of two normally distributed variables follow distribution. Density function of product of two correlated χ^2 variables U and V was derived by a complicated formula [50], which may be used to find distribution of *OPSI.*

Benefits

Proposed scores reflecting intensity of pain by continuous variable satisfying equidistant property and normality have the following advantages

- Generated scores are monotonic. Endorsement of (*j*+1)-th level of an item by a patient will give higher score than the choice of *j*-th level for *j*= 1, 2, 3, 4, and so on.
- Ensures admissibility of the operation "addition" and helps to find sample mean and SD of a group of patients and also to estimate population parameters: mean, variance and confidence interval of population mean from a large sample and to test statistical hypothesis H_0: $\mu_1=\mu_2$ against H_0: $\mu_1\neq\mu_2$ using *t*-statistic.
- Meaningful ranking and classification of patients with respect to the proposed scores.
- Assess progress/deterioration of a patient by $\frac{P_{it}-P_{i(t-1)}}{P_{i(t-1)}}$X 100 where P_{it} denotes the proposed measure of severity of *i*-th patient in *t*-th time period. The ratio reflects responsiveness of the scale and effectiveness of a treatment plan. A positive value of $\frac{P_{it}-P_{i(t-1)}}{P_{i(t-1)}}$ X 100 indicates pain intensity of the *i*-th patient has increased at *t*-th period over the previous period and require a relook to the treatment plan for the patient. Similarly, $\overline{P_t} > \overline{P_{(t-1}}$ indicates increase in average pain intensity for the group in the *t*-th period over (*t-1*)-th period and thus, require immediate action plan. SD (P_t)>SD $(P_{(t-1)})$ implies that pain intensity of the sample at the *t*-th period was more heterogeneous than the previous period.
- Possible to draw path of improvement/decline of one or a group of patients across time which may facilitate drawing useful conclusions including better prognostication.
- Different cut-off scores of different scales can be integrated by considering normally distributed scale score of each scale and finding equivalent scores (x_0, y_0) of two scales by solving the equation $\int_{-\infty}^{x_0} f(x)dx = \int_{-\infty}^{y_0} g(y)dy$ for a given value of say x_0 i.e. area of the curve f(x) for scale 1 up to x_0= area of the curve for scale 2 up to y_0 [51].The equation can be solved using standard normal table. Equivalent score-combinations by this approach are possible even if scales have different item formats or dimensions. Such equivalent cut-off scores are likely to give same results of ROC curve analysis for diagnosis by two scales. Equivalent scores of two scales are perfectly correlated and give equal reliability, validity, responsiveness of both the scales.
- Reliability in terms of Cronbach's alpha cannot be computed for a single-item measure of pain. Test-retest reliability is influenced significantly by the treatment during the time gap between two administrations of the scale. For example, test-retest reliability will be high even if pain intensity remains unaltered (zero effect of treatment) during the time gap. Method proposed by [52] can be applied to find theoretical reliability (ratio of true score variance and observed score variance) as $r_{tt} = 1 - \frac{2S_{Pg}{}^2(1-r_{gh})}{NS_P{}^2}$, where *N* denotes sample size; $S_P{}^2$ denotes sample variance; $S_{Pg}{}^2$ is variance of the g-th sub-test and r_{gh} is the correlation between the *g*-th and *h*-th sub-test (Split-half reliability).This involves dichotomization of the test in two parallel sub-tests say *g*-th and *h*-th.
- Validity of a multidimensional scale can be obtained as Factorial validity which is the ratio of the first eigenvalue to the sum of all eigenvalues to reflect validity of the of the main factor for which the test was developed [53].

Discussions

Major limitations of scales using summative Likert scores or NRS-scores can be avoided by the proposed method generating continuous, monotonic, normally distributed scores and facilitating better inferences like estimation of population mean (μ) variance (σ^2), confidence interval of testing statistical hypothesis like or $H_0: \mu_1 = \mu_2$ or $H_0: \sigma_1^2 = \sigma_2^2$ etc. from representative samples. Distribution of *OPS* is normal. Responsiveness of *OPS* and also effectiveness of treatment plan can be assessed by path of progress/deterioration registered by a patient or a group of patients between two successive time periods. Equivalent score combinations (x_0, y_0) were found where area under curve f(x) up to x_0 = area of the curve g(y) up to y_0 where f(x) and g(y) represent respectively normal pdf of X and Y.

Method described to obtain test reliability as per the theoretical definition. Normally distributed *P*-scores can be used to test against by *F*-test.

$H_0: r_{tt} = \frac{S_T^2}{S_X^2} = 1 \Leftrightarrow H_0: \sigma_X^2 = \sigma_T^2$ against $H_1: \sigma_X^2 > \sigma_T^2$ by *F*-test.

Validity of a multidimensional scale can be obtained as Factorial validity to reflect validity of the of the main factor for which the test was developed.

The index *OPSI* satisfies important properties like

- *OPSI* as aggregation of dimensions = *OPSI* as aggregation of components variables ensuring minimum trade-off among the dimensions or components.
- Easy assessment of relative importance of dimensions and components
- Dimensions or components $\frac{P_{ic}}{P_{i0}} < 0$ where are critical requiring attention of the physicians and care givers.

However, finding distribution of *OPSI* may not be easy.

The proposed measures improve quality of measurements of scale, facilitate meaningful comparisons across groups and time and are critically relevant to physicians, care givers and researchers in social and medical sciences.

Conclusions

Proposed method of transforming ordinal scores of K-point items to continuous, monotonic scores following normal distribution helps to avoid major limitations and undertake analysis under parametric set up. Suggested integration of several QoL scales has clear theoretical advantages. Assumption-free measures of reliability, validity, etc. may be used while comparing comprehensively areas of multidimensional QoL scales. From the angle of distribution, *OPS* may be preferred than *OPSI*.

Future studies with multi-data sets involving more than one QoL scales are suggested to investigate characteristics of overall pain status (*OPS)* and index of overall pain status *(OPSI)* along with clinically relevant issues and psychometric properties of the proposed transformations.

Declarations

- **Acknowledgement: Nil**
- **Competing Interests:** Nil.
- **Funding:** No funding was obtained for this study.
- **Data availability:** Not applicable as no datasets were generated or analyzed in the study.
- **Code availability:** No application of software package or custom code.
- **Authors' contribution:** The single author is involved in Conceptualization, Methodology, Writing- Original draft preparation, Writing- Reviewing and Editing.

Bibliography

1. Schug SA., *et al.* "The IASP classification of chronic pain for ICD-11: chronic postsurgical or posttraumatic pain". *Pain* 160 (2019): 45-52.
2. Rosenberger DC., *et al.* "Chronic post-surgical pain - update on incidence, risk factors and preventive treatment options". *BJA Education* 22.5 (2022): 190-196.
3. Pogatzki-Zahn EM., *et al.* "Postoperative pain-from mechanisms to treatment". *PAIN Reports* 2.2 (2017): e588.
4. Martinez V., *et al.* "Risk factors predictive of chronic postsurgical neuropathic pain: the value of the iliac crest bone harvest model". *Pain* 153.7 (2012): 1478- 1483.
5. Lavand'homme P. "Transition from acute to chronic pain after surgery". *Pain* 158.1 (2017): S50-S54.
6. Giusti EM., *et al.* "Psychological and psychosocial predictors of chronic postsurgical pain: a systematic review and meta-analysis". *Pain* 162.1 (2021): 10-30.
7. Glare P., *et al.* "Transition from acute to chronic pain after surgery". *Lancet* 393.10180 (2019): 1537-1546.
8. Schnabel A., *et al.* "Predicting poor postoperative acute pain outcome in adults: an international, multicentre database analysis of risk factors in 50,005 patients". *PAIN Reports* 5.4 (2020): e831.
9. Schug SA and Bruce J. "Risk stratification for the development of chronic postsurgical pain". *PAIN Reports* 2.6 (2017): e627.
10. Robinson A., *et al.* "The effectiveness of physiotherapy interventions on pain and quality of life in adults with persistent post-surgical pain compared to usual care: A systematic review". *PLoS One* 14.12 (2019): e0226227.

11. Meretoja TJ., *et al.* "Clinical prediction model and tool for assessing risk of persistent pain after breast cancer surgery". *Journal of Clinical Oncology* 35 (2017): 1660e7.

12. Althaus A., *et al.* "Development of a risk index for the prediction of chronic post-surgical pain". *European Journal of Pain* 16 (2012): 901-910.

13. Montes A., *et al.* "Presurgical risk model for chronic postsurgical pain based on 6 clinical predictors: a prospective external validation". *Pain* 161.11 (2020): 2611-2618.

14. Silva PA., *et al.* "Cut-off point for WHOQOL-bref as a measure of quality of life of older adults". *Revista de Saúde Pública* 48.3 (2014): 390-397.

15. Lidington E., *et al.* "Identifying health-related quality of life cut-off scores that indicate the need for supportive care in young adults with cancer". *Quality of Life Research* 31 (2022): 2717-2727.

16. Obuchowski NA. "Receiver operating characteristic curves and their use inradiology". *Radiology* 229 (2003): 3-8.

17. Gagliese Lucia., *et al.* "The measurement of postoperative pain: A comparison of intensity scales in younger and older surgical patients". *Pain* 117.3 (2005): 412-420.

18. Aun C., *et al.* "Evaluation of the use of visual analogue scale in Chinese patients". *Pain* 25 (1986): 215-221.

19. Williamson A and Hoggart B. "Pain: a review of three commonly used pain rating scales". *Journal of Clinical Nursing* 14 (2005): 798-804.

20. Myles PS., *et al.* "Measuring acute postoperative pain using the visual analog scale: the minimal clinically important difference and patient acceptable symptom state". *British Journal of Anaesthesia* 118.3 (2017): 424-429.

21. Jensen Mark P., *et al.* "The measurement of clinical pain intensity: a comparison of six methods". *Pain* 27.1 (1986): 117-126.

22. Kwong WJ and Pathak DS. "Validation of the eleven-point pain scale in the measurement of migraine headache pain". *Cephalalgia* 27 (2007): 336-342.

23. Le Resche L., *et al.* "Reliability of Visual Analog and Verbal Descriptor Scales for "Objective" Measurement of Temporomandibular Disorder Pain". *Journal of Dental Research* 67.1 (1988): 33-36.

24. Jensen MP and Karoly P. "Self-Report Scales and Procedures for Assessing Pain in Adults". In: Turk, D.C. and Melzack, R., Eds., *Handbook of Pain Assessment*, 3rd Edition, Guilford Press, New York (2011): 15-34.

25. Rosier EM., *et al.* "Reproducibility of pain measurement and pain perception". *Pain* 98 (2002): 205-216.

26. van Dijk JF., *et al.* "The relation between patients' NRS pain scores and their desire for additional opioids after surgery". *Pain Practice* 15.7 (2015): 604-609.

27. Coll AM., *et al.* "Postoperative pain assessment tools in day surgery: literature review". *Journal of Advanced Nursing* 46.2 (2004): 124-133.

28. Laycock HC and Harrop-Griffiths W. "Assessing pain: how and why?" *Anaesthesia* 76 (2021): 559-562.

29. Baamer RM., *et al.* "Utility of unidimensional and functional pain assessment tools in adult postoperative patients: a systematic review". *British Journal of Anaesthesia* 128.5 (2022): 874-888.

30. van Boekel RLM., *et al.* "Moving beyond pain scores: Multidimensional pain assessment is essential for adequate pain management after surgery". *PLoS ONE* 12.5 (2017): e0177345.

31. Melzack R. "The McGill Pain Questionnaire: major properties and scoring methods". *Pain* 1.3 (1975): 277-299.

32. Graham C., *et al.* "Use of the McGill Pain Questionnaire in the assessment of cancer pain: replicability and consistency". *Pain* 8.3 (1980): 377-387.

33. Cleeland C and Ryan K. "Pain assessment: global use of the Brief Pain Inventory". *Annals of the Academy of Medicine of Singapore* 23.2 (1994): 129-138.

34. Barber MD. "Validation of the Surgical Pain Scales in women undergoing pelvic reconstructive 215 surgery". *Female Pelvic Medicine and Reconstructive Surgery* 18.4 (2012): 198-204.

35. Closs SJ., *et al.* "Towards improved decision support in the assessment and management of pain for people with dementia in hospital: a systematic meta-review and observational study". *Health Services and Delivery Research* 4.30 (2016): 1-162.

36. Costardi D., *et al.* "The Italian version of the pain assessment in advanced dementia (PAINAD) scale. *Arch Gerontol Geriatrics* 44.2 (2017): 175-180.

37. Cella DF. "Quality of life: concepts and definition". *Journal of Pain and Symptom Management* 9.3 (1994): 186- 192.

38. Chaichana KL., *et al.* "Correlation of preoperative depression and somatic perception scales with postoperative disability and quality of life after lumbar discectomy". *Journal of Neurosurgery: Spine* 14.2 (2011): 261-267.

39. Ware J., *et al.* "A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity". *Medical Care* 34 (1996): 220-233.

40. Maillard J., *et al.* "Preoperative and early postoperative quality of life after major surgery - a prospective observational study". *Health Qual Life Outcomes* 13 (2015): 12.

41. Odom SL Boyd B., *et al.* "Evaluation of comprehensive treatment models for individuals with autism spectrum disorders". *Journal of Autism and Developmental Disabilities* 40 (2010): 425-437.

42. NHS Quality Improvement Scotland. "The Impact of Nursing on Patient Clinical Outcomes". Edinburgh: NHSQIS (2005).

43. Essink-Bot ML., *et al.* "An empirical comparison of four generic health status measures. The Nottingham Health Profile, the Medical Outcomes Study 36-item Short-Form Health Survey, the COOP/WONCA charts, and the EuroQol instrument". *Medical Care* 35.5 (1997): 522-537.

44. Clason DL and Dormody TJ. "Analyzing data measured by individual Likert-type items". *Journal of Agricultural Education* 35.4 (1994): 31-35.

45. Harwell MR and Gatti GG. "Rescaling ordinal data to interval data in educational research". *Review of Educational Research* 71 (2001): 105-131.

46. Šimkovic M and Träuble B. "Robustness of statistical methods when measure is affected by ceiling and/or floor effect". *PloS One* 14.8 (2019): e0220889.

47. Yusoff Rohana and Janor RM. "Generation of an Interval Metric Scale to Measure Attitude". *SAGE Open* (2014): 1-16.

48. Chakrabartty SN. "Optimum number of Response categories". *Current Psychology* 42 (2023): 5590-5598 (2023).

49. Chakrabartty SN. "Equidistant Likert as weighted sum of Response Categories". *Cultura, Educación y Sociedad* 14.1 (2023): 75-92.

50. Joardar AH and Omar MH. "On Statistical Characteristics of the Product of two correlated Chi-square variables". *Journal of Applied Statistical Science* 9.4 (2013): 1067-5817.

51. Chakrabartty and Satyendra Nath. "Disability and Quality of Life". *Health Science Journal* 16.12 (2022): 1-6.

52. Chakrabartty and Satyendra Nath. "Reliability of Test Battery, *Methodological Innovations* 13.2 (2020): 1-8. DOI: 10.1177/2059799120918340

53. Parkerson HA., *et al.* "Factorial Validity of the English-Language Version of the Pain Catastrophizing Scale-Child Version". *The Journal of Pain* 14.11 (2013): 1383-1389, https://doi.org/10.1016/j.jpain.2013.06.004