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Pain measurement methods and pain measurement system design

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ABSTRACT

The measurement of pain, which is one of the common problems of human beings, is extremely important in terms of determining the method and program that is planned to be applied to eliminate it. Therefore, the most important step in pain treatment will be to determine the pain value first. Today, there are many methods used to assess pain. In this article, the importance of pain assessment, the methods used in pain assessment and the importance of the algometer device, which is widely used in the pain assessment process, will be discussed. In addition, the features of the algometer device designed with tension spring and potentiometer structure will be explained.

Key words: Pain, pain assessment, algometer**.**

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Introduction

Pain, which is a universal condition that humanity has been trying to explain for centuries, continues to hold significance in the field of medicine today. The word 'pain' originates from the Latin word 'poena' (torture, punishment, revenge), and its definition is quite intricate. In connection with this matter, the International Association for the Study of Pain (IASP) has defined pain as follows: Pain is an unpleasant sensory and emotional experience that accompanies existing or potential tissue damage or can be identified by this damage. As discerned from the definition, pain is always a subjective condition because it is an unpleasant concept. It can profoundly affect the quality of human life and bodily behavior. Pain represents a subjective force that endeavors to cope with the underlying organic cause. In the literature, it is acknowledged that pain is more than just a symptom; it is a condition in itself (Araujo and Romero, 2015). The American Pain Association declared in 1996 that pain is the fifth vital sign of life. As per this definition, it underscores that pain should be considered one of the essential human vital signs, and pain assessment should undoubtedly be taken into account when assessing vital signs [1]. It has been emphasized that the assessment of pain, which involves physiotherapists, anesthesiologists, and other healthcare professionals if necessary, is vital and should be embraced by the team comprised of the patient, physician, and nurse. Notably, nurses play more significant roles in this team due to their extended interaction time with patients [2,3]. The patient's care process primarily commences with pain assessment. Pain should be assessed and managed routinely during treatment. Pain evaluation during this process should occur during regular staff shifts, before and after surgical interventions, at defined intervals according to the type of surgery and the anticipated intensity of pain, and upon reporting of new pain. Furthermore, it should be performed thirty minutes after parenteral analgesic administration and sixty minutes after oral procedures [4]. Determining the pain threshold value is crucial as it shapes the treatment method and plan. Additionally, assessing pain values during the treatment process is pivotal for determining the appropriateness of the treatment. It is of paramount importance that pain values are assessed using a standardized schedule accepted by the relevant field to establish a common language for effective communication among medical personnel [5]. To assess pain accurately and as objectively as possible, various methods are employed. When categorizing pain, consideration must be given to its subjectivity alongside its physical dimension, with the patient's pain report serving as the foundational element. This is because individual differences can lead to variations in the perception, identification, and reaction to pain. The assessment of a patient experiencing pain typically begins with observation. It involves observing the patient's facial expressions in response to pain, such as grimacing, moaning, or touching the painful area, among other behaviors [6]. Due to the subjective and individual nature of pain, extensive research has been conducted in the realm of pain assessment in recent years. Ensuring the active involvement of the patient in pain determination is crucial. Especially in one-dimensional scales where patients self-evaluate, it is imperative that patients comprehend and interpret the evaluation criteria and provide the most accurate assessment for themselves. Hence, the choice of pain scale for the patient holds significant importance [7,8]. The frequency and duration of pain play a pivotal role in diagnosis and classification. Given its subjective nature, the most crucial factor in accurately evaluating pain is its severity.

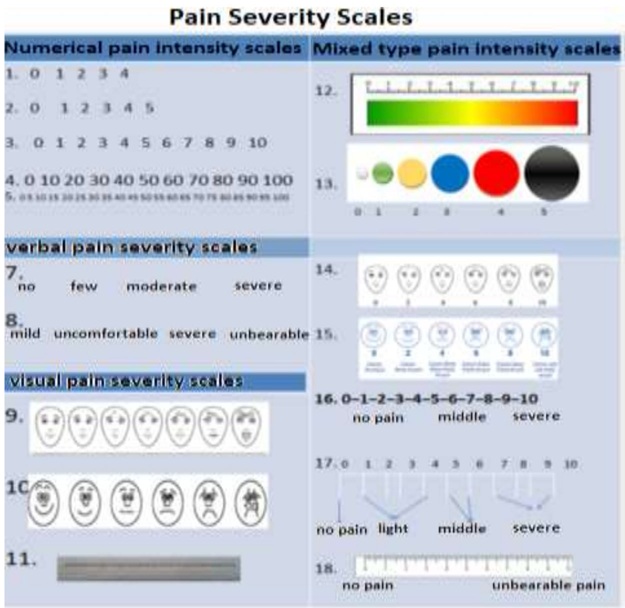

Figure 1. Grouped pain severity scales.

Here we can categorize the preferred methods for measuring and assessing pain into two categories: one-dimensional and multidimensional methods [9,10]. In recent years, the use of the algometer device in the healthcare field has been extensively studied. Caroline de Castro Moura et al. noted in their study that chronic low back pain leads to physical, functional, and emotional disabilities. They explored the effects of auricular acupuncture combined with cupping therapy on individuals with chronic back pain. Their study focused on a group of patients aged 18-70 years with chronic back pain (cervical, thoracic, and/or lumbar). They randomly divided 198 participants into two groups: 'ear acupuncture' and 'ear acupuncture and cupping therapy.' Data were collected at three different points: before the initial session with the patient (baseline), after the final session (post-treatment), and seven days after the conclusion of treatment (follow-up). Data collection tools included the Brief Pain Inventory, a digital algometer, and the Rolland Morris Disability Questionnaire. They employed the Generalized Estimation Equation model to examine the relationship between outcomes and pain severity. The results indicated that auricular acupuncture combined with cupping therapy was more effective in treating chronic back pain than auricular acupuncture alone. This study demonstrates the utility of the algometer device in pain measurement processes [11]. Ray Postuma et al. conducted a study on the association between abdominal pain sensitivity values and the diagnosis of appendicitis in children. They emphasized the difficulty of defining the severity of abdominal pain in children due to its subjective nature. They measured abdominal wall pressure-pain thresholds and tenderness localization rates using an algometer in children with suspected appendicitis who were referred to the pediatric general surgeon. The results were correlated with the final diagnosis, standard diagnostic scores, and abdominal ultrasound. Their experimental studies suggest that the algometer can serve as a precise measure for clinical practice, documentation, and research [12]. In their study, Phebe De Heus et al. highlighted pressure algometry as an objective tool for measuring mechanical nociceptive threshold (MNT) values and musculoskeletal responses. They noted the lack of scientific evidence for objectively assessing neck and back musculoskeletal tenderness in horses. In their research, they aimed to evaluate the use of pressure algometry to objectively measure the effect of diagnostic palpation performed by physiotherapists on the horse's neck and back musculoskeletal function. They also tested the inter-rater reproducibility of animal physiotherapists and objectively compared subjective clinical scores for vertebral column area with MNT values measured at the same sites to explore the potential clinical application of pressure algometry in daily equine rehabilitation practice. In the study, six adult Dutch Warmblood riding school mares were randomly assigned to an experimental or control group, and the MNT of all horses was measured at 35 predefined sites in the vertebral column in the morning and evening of the same day. This study demonstrates the application of the algometer device in this field, yielding beneficial results [13]. S. Starita et al. investigated whether adhesive capsulitis (AC), a condition causing limited shoulder movement, can affect the healthy shoulder if it occurs unilaterally. In their review, they discussed the clinical and kinematic differences between a healthy shoulder and a shoulder affected by capsulitis before and after a conservative physiotherapy protocol. The humeral flexion/abduction movements of 10 patients with unilateral AC were evaluated using inertial and magnetic (IMU) sensors. Specifically, they used the ISEO protocol to assess differences in humeral range of motion between the pathological and healthy shoulder and assessed pain sensitivity via an algometer. The study revealed that the ISEO protocol is an effective approach for quantitatively evaluating physical therapy efficacy in AC. They stated that while physical therapy did not improve range of motion in the healthy shoulder, it significantly improved pain sensitivity in bilateral patients. This study underscores the suitability of the algometer device for use in the field of physical therapy [14]. Manuela Deodato and colleagues examined the effect of manual therapy and pelvic floor exercises on the reduction of primary dysmenorrhea pain, one of the most common causes of pelvic and low back pain. The aim of their study was to evaluate the efficacy of manual therapy (MT), pelvic floor exercises (PFE), and their combination (MT + PFE) in improving clinical outcomes and pain sensitivity in women with primary dysmenorrhea. A prospective observational study was conducted with thirty women (25.0 ± 6.1 years) who had a history of primary dysmenorrhea. These women attended eight 60-minute sessions of MT, PFE, or MT + PFE twice weekly. They received different treatments based on the services offered in the field of physiotherapy. A 0-10 numerical rating scale (NRS) was used to assess subjective pain, and the Short Form 36 (SF-36) was used to assess quality of life. Pressure pain threshold (PPT) measurements were taken at various pelvic and lumbar regions using an algometer device. The study highlighted the importance of recommending physiotherapy treatments to women with primary dysmenorrhea to improve their symptoms. The combination of manual therapy and active pelvic floor exercise was found to yield the best results, including improvements in lumbar pain thresholds [15].

Pain assessment methods

One-dimensional and multidimensional scales have been developed for monitoring the treatment process and initial pain assessment. One-dimensional scales are intended solely for assessing pain severity. Patients are asked to evaluate their pain severity using mixed scales developed through verbal, numerical, or visual methods. Multidimensional scales, on the other hand, inquire about various variables such as pain location, severity, type, timing, triggering and alleviating factors, and the patient's expression of pain (Figure 1) [3,7].

1) One-dimensional methods used in pain measurement: These methods typically measure the extent of pain and the reduction level of pain. Some methods in this category include: 1.1) Category Scales: These scales consist of words that describe pain with increasing severity. The defined words are arranged as follows: mild, discomforting, severe, very severe, unbearable. Additionally, a similar structure ranks the severity level on a 4-point pain scale as follows: no pain, mild pain, moderate pain, severe pain (Figure 1) [9,10,16].

1.2) Visual analog scale (VAS): This method is a simple and reproducible technique that requires minimal equipment. It involves a 10 cm line where the left end indicates the absence of pain, and the right end indicates unbearable pain. Patients are asked to mark the point on this line that corresponds to the intensity of the pain they are experiencing. The distance from the marked point to the endpoint provides a numerical index of pain severity. While this method is straightforward, it is crucial to clearly explain the endpoints to patients for accurate measurements (Figure 1) [9,10,16].

1.3) Numerical rating scales (NRS): Structurally similar to VAS, NRS employs numerical values divided into equal increments on a line. Values can range from 0-5, 0-10, or 0-100. A score of 0 indicates no pain, while higher values represent more severe pain (Figure 1) [9,10,16].

1.4) Box scale: This numerical rating scale comprises boxes containing numbers from 0 to 10, arranged from top to bottom. A score of 0 indicates no pain, and 10 refers to the most severe pain (Figure 1) [9,10,16].

2) Multidimensional methods used in pain measurement: These methods not only assess pain severity but also gather information about the location and nature of the pain, whether it is superficial or deep.

2.1) McGill pain questionnaire (MPQ): Developed by Melzack and Katz in 1971, this questionnaire presents patients with a form asking them to choose the most suitable options for describing their pain. The form comprises four parts: location of pain, qualities of pain, time pattern of pain, and pain intensity descriptors [13].

2.2) West Haven-Yale multidimensional pain inventory: Developed by Kerns and colleagues in 1985, this tool is psychometrically sound and based on a cognitive-behavioral perspective for assessing the pain experience in patients with chronic pain. It aims to provide a comprehensive yet concise evaluation of pain [13].

2.3) Memorial pain assessment card: This method assesses the analgesic efficacy in severe cases of pain. It evaluates both pain intensity and pain reduction using the VAS method while also considering the patient's psychological state [16,13].

2.4) Short pain inventory: This multidimensional pain assessment method provides information about the current magnitude of pain experienced by patients using a numeric scale ranging from 0 to 10. It also factors in pain relief from medication and treatment, as well as the impact of pain on the patient's quality of life [10,16]. In addition to the mentioned pain measurement methods, there are numerous other methods still in use, including the Pain Discomfort Scale, Pain Detection Profile, and Descriptive Differential Scale [10,13].

Pain threshold

The most effective means of detecting pain is to determine its presence. In medicine, the presence of pain is generally ascertained through a standardized stimulus. Researchers focus on the minimum intensity of stimulation required to induce pain, known as the pain threshold value. The threshold value is the lowest energy level necessary to elicit a sensation. Threshold values are determined based on the stimulus used, such as temperature (in degrees Celsius) or mechanical forces (in kilograms or Newtons) [14].

Figure 2. Analog type algometer.

Figure 3. Analog type algometer usage.

Algometer

An algometer, also known as a dolorimeter, has been developed to objectively assess pain tolerance and pain threshold. Fischer [15] and Fischer and Chang [16] have indicated that the algometer device can be employed to identify tender areas on muscles and to evaluate the effects of treatment on painful muscle stiffness (trigger points). To accurately assess trigger points, muscles should be relaxed. The algometer's tip is placed on the most sensitive point at a 90° angle, and pressure is gradually increased until the patient verbally expresses discomfort. This process can be repeated multiple times, and the average of the determined values is recorded. Typically, measurement repetitions are spaced approximately 30 to 60 seconds apart on average. The measurement results obtained using the algometer device are more valid and reliable as they assess durability in response to applied pressure, considering both their discourse and reaction to the pressure (Figure 2,3).

Algometer design with Tensile Spring – Potentiometer Structure

In this design, we have employed a spring of suitable size and tensile strength to counteract the applied force. When a 10 kg/F force is applied, the spring stretches to a height of approximately 10 cm. Utilizing a tension spring in this structure, the internal components move vertically. Thanks to a gear mechanism situated on the outer surface of the internal structure, it imparts rotational motion to the potentiometer located in the center. The potentiometer's value varies in accordance with the rate of rotation. The altered resistance value is then read using a microcontroller, and after performing the necessary calculations using the corresponding formula, it is displayed on the screen.

Figure 4. Algometer with Spring and Potentiometer structure.

In the system design, the external structure of the device was designed using 3D modeling software, and it was subsequently manufactured using a 3D printer. A 1 K ohm potentiometer was employed to measure the rotation rate. An Arduino Pro Mini, powered by a 7.4-volt battery, was used as the microcontroller, and an OLED LCD screen was utilized for visual feedback (Figure 4,5).

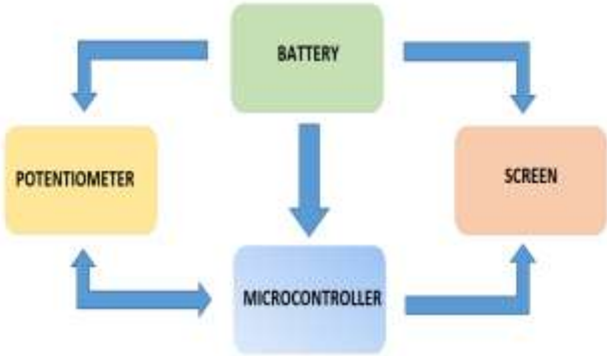

Figure 5. Algometer working diagram with Spring and Potentiometer structure.

The absence of a mechanical structure in the system allows the device to be used for an extended period without any issues. The easy and cost-effective availability of the tools used in the design will lead to an increase in both production rates and usage. Furthermore, the designed device can be enhanced with additional features such as a memory recording function, data transmission to devices like mobile phones and tablets, and remote access. The amount of tension in the spring will vary depending on the type and diameter of the wire used in the spring. Measurements can be taken for every 500-gram increment within the range of 0-10 kg. To achieve even more precise measurements, an additional reduction mechanism can be designed for the gear mechanism.

Conclusion

Detecting and addressing pain that prompts patients to seek medical attention and negatively impacts their quality of life is of paramount importance. Evaluating pain and administering the appropriate form of treatment are essential steps in the healthcare process. Given the subjective nature of pain and its variability from person to person, objective measurement can be challenging. Factors such as the patient's gender, age, ethnicity, as well as ongoing psychological and economic issues have been observed to influence the expression of pain. Since pain is unique to each individual, it is crucial to thoroughly understand the patient, conduct continuous observations, gather a comprehensive medical history, and determine appropriate treatment methods.

Recording results using valid and reliable measurement tools is essential in the evaluation of pain, with priority given to the patient's self-report, identification of potential pathological or deformity-related causes of pain, and observation of physiological and personal behaviors. Accurate pain assessment and effective communication in a medical context have proven to be highly beneficial during the treatment phase. Establishing the pain threshold value is integral to a precise pain assessment. The tests conducted have confirmed the validity and reliability of the algometer measuring device developed for measuring pain threshold values.

Furthermore, the spring-potentiometer algometer device that we designed has undergone testing by field experts, and it has been determined to be suitable for use in the field of Physical Therapy, receiving positive feedback.

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References

[1]NPC and JCAHO (National Pharmaceutical Council Joint Commission on Acreditation of Health Care Organizations). Pain: Current Understanding of Assessment Management and Treatments. Editor: Patricia H. Berry, C Richard Chapman, Edward C Covington, June L, DahlJeffery A, Katz Christine Miaskowski & Michael J, Mclean. 2001;s21 http://www.npcnow.org/system/files/research/download/Pain-Current-Understanding-of-Assessment-Management-and-Treatments.pdf (04 Nisan 2016).

[2]Deniz B, Çöçelli, LP, Ovayolu, N, et al. The Evaluation of Interventions for Pain Control Done by Health Staff Caring the Patient. Ağrı. 2008; 20(3):26-36.

[3]Yesilyurt M, Faydalı S. Use of One-Dimensional Scales in Pain Assessment. Journal of Anatolia Nursing and Health Sciences. 2020; 23(3): 444-451.

[4]Eti-Aslan F. Dahili ve Cerrahi Hastalıklarda Bakım. Editörler: Karadakovan A. Eti-Aslan F. Akademisyen Kitabevi, 2014, 3. Baskı, Ankara, Türkiye, s:127-48.

[5]Eti-Aslan F. Ağrı değerlendirme yöntemleri. Cumhuriyet Üniversitesi Hemşirelik Yüksekokulu Dergisi. 2002; 6(1):9-16.

[6] Çelik S. Yoğun Bakım Hastalarında Ağrı Yönetimi.2016. Yoğun Bakım Hemşireliği Dergisi. 2016;20(1):1-8
[7] Wysham NG, Miriovsky BJ, Currow DC, et al. Practical Dyspnea Assessment: Relationship Between the 0-10 Numerical Rating Scale and the Four-Level Categorical Verbal Descriptor Scale of Dyspnea Intensity. J Pain Symptom Manage. 2015;50(4):480-7.
[8] Tan S, Özyurt G. Hastaların en kolay anladığı ağrı değerlendirme yöntemi hangisidir? Anestezi Dergisi. 2006; 14(3): 171-5.
[9] Oğuz, H. (1995). Kronik Ağrı Tedavisi. H. Oğuz (Ed.). Tıbbi Rehabilitasyon (s: 685-693). İstanbul: Nobel Tıp Kitabevleri.
[10] Rome J. Mayo (2002). Clinic Kronik Ağrı (G. Akyüz, H. Gündüz, Çev.) Ankara: Palme Yayıncılık 2002.
[11] Moura CC, Chaves ECL, Nogueira DA, et al. Effects of ear acupuncture combined with cupping therapy on severity and threshold of chronic back pain and physical disability: A randomized clinical trial. J Tradit Complement Med. 2021;12(2):152-161.
[12] Postuma R, Vajcner G, Postuma RB. Bedside pressure-pain threshold algometry to measure abdominal tenderness in childhood appendicitis: A retrospective cohort study, Int J Surg Open. 2021;32:1-10.
[13] Türkoğlu, M.. Ağrının Tanımlanması ve Ölçümü. Yegül, İ. (Ed). Ağrı ve Tedavisi. 1993. s19-28. İzmir: Yapım Matbaacılık.
[14] Gürel OK, Taraktaş A, Kurtuluş D, et al. Pressure Pain Threshold in Musculoskeletal Disorders. Boğaziçi Tip Dergisi; 2017; 4(2): 77-83
[15] Fischer AA. Diagnosis and management of chronic pain in physical medicine and rehabilitation. Ed: Ruskin AP, Current Therapy in Physiatry. pp. 123-145, Saunders, Philadelphia, PA, 1984.
[16] Fischer AA, Chang C. Temperature and pressure threshold measurements in trigger points. Thermology. 1986;1:212-215.