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Orthopaedic belts using Sodium Acetate crystals

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Abstract - **The study involves the invention of an Orthopaedic Belt which facilitates potential heat therapy through gel packs, consisting of saturated solution of Sodium Acetate Trihydrate. Exothermic reaction of the solution produces the desired treatment temperature. The optimal concentration of the Sodium Acetate Trihydrate solution is determined with the help of Value Assessment Principle and Scale Narrow Down approach. The approach towards the invention of Orthopaedic belt involves two major processes namely, the Belt Fabrication and the Therapeutic Gel Preparation. The Backing layer, Pocket layer, Base layer, Elastic straps, Hook and loop attachments, Gel packs are the integral parts of the belt fabricated. The treatment gel is prepared based on Value Assessment (VA) Principle and Scale Narrow Down Approach. The VA principle determines the optimal solute to solvent ratio which is required to produce the required treatment temperature of 55°C. The Scale Narrow Down approach reduces the number of computations which are required to determine the desirable output. Among various concentrations of Sodium Acetate Trihydrate, the solute concentration of 164g in a constant 30 ml of distilled water can produce a temperature of 50°C to 55°C under normal room conditions for a considerably longer duration. The gel packs can be reused by dipping the solidified packs into boiling water at 85°C to 95°C. The current invention addresses some of the major drawbacks associated with the existing electrical packs and gel packs. The manual crystal loading method and rechargeability enhances the efficiency of gel packs by preventing accidental activation and other related issues. This Orthopaedic belt can be customized for any zone of impact.**

Keywords - **Heat therapy, Phase change materials, Sodium Acetate Trihydrate, Gel packs, Orthopaedic belt, Crystal loading method**

1. INTRODUCTION

Chronic pain can be regarded as the pain which persists longer than its normal healing time thereby lacking the response produced by the sensory nervous system [1]. Application of heat is the most common and ancient method of treatment for various ailments. Heat therapy, also known as thermotherapy, is the use of heat in therapeutic purposes for pain relief and other issues pertaining to the tissue damage [2][3]. Applying heat to the affected areas will decrease the transmission of pain signals to the brain and partially relieves the discomfort. Vasodilation refers to the widening of blood vessels and it facilitates the necessary augmentation of convective heat loss during environmental heat exposure. Inflammatory response takes place when the tissues are damaged by various external sources and this in turns results in the release of chemicals including histamine, bradykinin etc. [4]. Dry heat therapy includes the usage of hot cloth, hot water bottle, ultrasound, heating packs and many others [2][5]. These methods are of immense relief and benefit to those people with arthritis and stiff muscles, and injuries linked to the deep tissues of the skin [6]. In case of existing chemical packs, the chemical can be activated by either striking, kneading, or squeezing the packet, which in turn produces the heat [2]. The amount of heat generated depends upon the type of chemical employed and their phase changing ability. Phase change materials (PCM) are substances which can absorb large amount of latent heat during the processes such as melting, freezing etc. These materials have high energy density and isothermal operation in energy storage applications [8]. Sodium Acetate Trihydrate is one of the most efficient phase change materials because of its large latent heat of fusion (about 240 J/g) [7]. When they are heated past the melting point (around 58°C) and subsequently allowed to cool, the aqueous solution becomes saturated. On introducing its crystal form into the supersaturated solution, the liquid crystallizes and liberates the stored latent heat. The major outcome of this reaction is the ample amount of heat produced. The existing chemical packs involve the exact mechanism. However, some of the major drawbacks associated with them include lack of support across the area of use, the disc activation technique, higher temperatures of heating etc.

This article involves the invention of an orthopaedic belt consisting of chemical packs employing the sodium acetate trihydrate for potential heat therapy. The efficient heat needed for the treatment is produced by the exothermic chemical reaction of gel material which is made up of distilled water and sodium acetate crystals. The optimal solute to solvent ratio for efficient heat production by sodium acetate trihydrate is determined by employing the concepts of Value Assessment Principle and Scale Narrow down Approach [9].

2. MATERIALS AND METHODS

The methods involved in the make of Orthopaedic belt starts with the gel preparation. The prepared gel is filled into the gel packs and is inserted into the fabricated Orthopaedic belt. With the help of supportive straps, the belt can be worn over the affected area. Hence the entire methodology can be divided into two major processes.

2.1 ORTHOPAEDIC BELT FABRICATION

The individual components involved in the construction of the belt are: Backing layer, Pocket layer, Elastic straps, Hook and loop attachments and Gel packs as shown in Figure 1. The backing layer (102) and pocket layer (103) are made from cotton fabric with rectangular cut-out. These layers differ in terms of their dimensions, the presence of window and placement of hook and loop material. The pocket layer is smaller in dimension when compared to that of backing layer and a window is made at the centre for exposing the gel pack on the treatment area. After the pocket and backing layer is ready, the former is stitched to the later with the help of hook and loop material near its mouth (106), thereby facilitating its opening and closing for the insertion and removal of gel pack. This entire setup with backing layer and pocket layer is collectively termed as the base layer (105). Once this setup is ready, the base layer can be attached using the elastic material (104). This can be achieved with the hook material at its edges of the elastic material (107), with the counter loop material attached to the top of base layer for housing the elastic strap, thereby giving sufficient strength and grip throughout the treatment duration. The gel packs are formulated and housed inside the base layer pocket for heat therapy

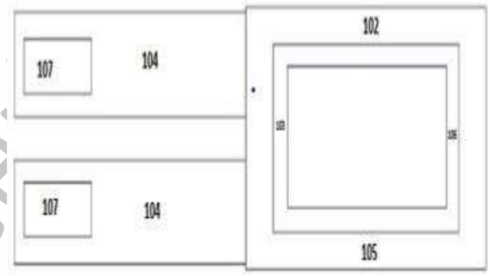

Fig. 1 Orthopaedic belt design

2.2 THERAPEUTIC GEL PREPARATION

The preparation of the optimal sodium acetate trihydrate solution involves the Value Assessment (VA) principle and the Scale Narrow down approach [9]. The solute and solvent are sodium acetate crystals and water, respectively. Value assessment principle is the key to find the sodium acetate quantity required for heat therapy (i.e.) the optimal solute to solvent ratio. Scale narrow down approach is a useful tool to reduce the computation needed to reach the desirable output. Let us assume the solute quantity to be X; and the solvent quantity to be Y. The ratio will be the heat produced and this can be represented as (1),

$$\text{STS ratio} = X/Y \quad (1)$$

The solvent concentration Y is maintained as 30 ml throughout the process according to the VA principle and hence the value of X will be computed using the scale narrow down approach to get the appropriate clinical heat range of 55°C to 60°C. This approach involves assuming an initial value of X say 'z'. The scaling factor is fixed as 's' as in (2). During trial 1,

$$X = s + z \qquad (2)$$

The scaling factor for the next trial is incremented or decremented based on the results obtained during trial 1 as given in (3). By repeating this method, the difference between the actual values obtained and the desirable value decreases, thereby yielding the temperature value.

Temperature difference (ϴ) = Desirable temperature (D) - Observed peak temperature (On) (3)

Where n = 1, 2, 3.... etc. The desirable temperature is considered as 55°C. The calculations begin with initial z value as 0 and scaling factor as 50 g. Since no crystallization takes place, the scaling factor is incremented, and the temperature difference is calculated. Modifications are continued till the temperature difference close to 0 is obtained. Upon achieving the exact heat liberating gel solution, the gel is sealed within polyethylene polymer pack. The gel packs can also be made using other polymers of low density. The mouth of gel packs has a zip-lock arrangement for closing and opening during times of activating the gel solution, discarding the used solution, and recharging the fresh reaction solution. The Bottom of gel pack has an extending arrangement to hold an additional gel treatment solution.

Fig. 2 Preparation of Gel Solution

3. RESULTS AND DISCUSSION

Based on the calculations performed using the VA principle and scale narrow down approach, Table 1 illustrates the temperature difference, and the peak temperature values are computed with a constant solvent quantity of 30 ml. The temperature difference between the ideal heat therapy temperature of 55°C and the peak exothermic heat, On coincides with each other at a solute quantity of 164g. In addition to this, the solute concentration also acts as large duration heat producer. The chemical packs prepared using the above formulation can produce 50°C to 55°C temperature under normal room conditions, which is very well within the bearable range. The entire reaction is completely reversible and hence the liquid solution can be obtained by dipping the solidified gel pack into boiling water of 85°C to 95C. In this Orthopaedic belt, the manual crystal loading technique allows the user to introduce the reaction initiator capsules straight onto the gel packs to start the chemical reaction, just before the time of application. The Pocket has windows to expose the gel packs over the skin of the user and helps in uniform heat decimation as shown in Figure 3.

Fig. 3 Fabricated orthopaedic bet

Further these gel packs act as a barrier in separating the reaction solution to be brought in direct contact with the user. The gel packs are rechargeable and hence can be refilled with fresh solution and continued for use. The gel packs have been found to work well for about 10 trails and gradually undergoes a decrease in temperature with increase in the trails, thereby indicating the time of recharge.

Table I. Observation

Sample	Initial value of X, z (g)	Scaling factor, s (g)	Solute quantity, X (g)	Peak temperature, On (°C)	Temperature difference,Ө (°C)
A	0	50	50	-	-
B	50	50	100	42.15	12.85
C	100	25	125	45.1	9.9
D	125	25	150	47.8	7.2
E	150	5	155	50.1	4.9
F	155	5	160	50.4	4.6
G	160	2	162	50.6	4.4
H	162	2	164	55.35	-0.35

The Gel packs are made from polyethylene plastic polymers, which are capable of holding the clinical range of heat produced by the system. Orthopaedic belt of same design can be fabricated for different site of actions as shown in Figure 4. The two major existing techniques which are widely used to produce heat therapy are the electrical heating belt and the gel-filled heat packs. In case of electrical heating belts, some of the major discrepancies associated with them include the constant requirement of power supply throughout the working duration rendering them non-economical, hazardous effects on the treatment area such as macro shocks due to improper insulation, efficiency drop due to component failure etc. Whereas in case of the existing gel-filled heat packs, some of the major drawbacks includes the disc-activation technique which increases the possibility of accidental activation of gel packs, adverse effects on treatment area due to unprecedented amount of heat production, lack of support over the treatment area etc.

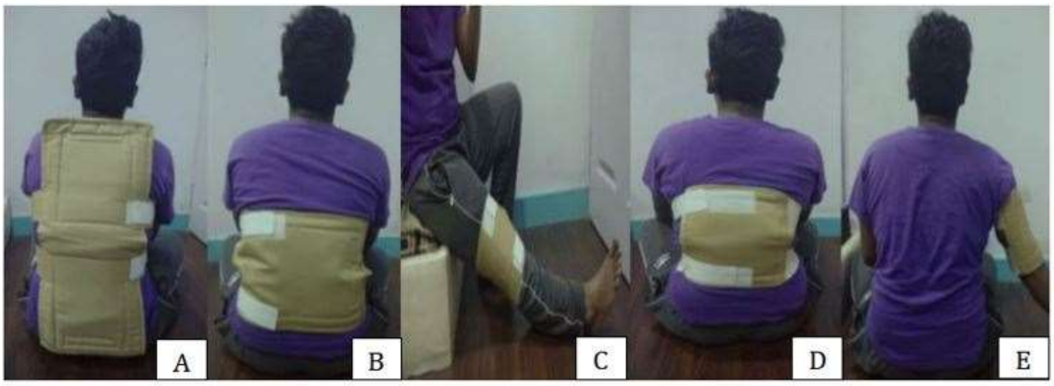

Fig. 4 Different types of belts (A) Back belt (B) Long hip belt (C) Knee belt (D) Short hip belt and (E) Elbow belt

4. CONCLUSION

The current orthopaedic belt offers greater advantages in comparison to the above described techniques in section 4. The use of exothermic chemical reaction overcomes the shortcomings of electrical system such as constant power supply requirements and current leakages. The elastic straps impart flexibility, thereby offering greater support to the treatment area. Double layer insulation prevents leakage of chemicals and since the whole belt is made of cotton fabric, accidental reaction of chemical with the material causes no harm to the user. The belt can bend according to the treatment area to a greater extent. Crystal loading method demands the user to open the gel pack to drop the capsule and initiate the reaction, thereby preventing accidental activation and saving the efficiency of usage. The rechargeability of gel pack and low efficiency drops make the whole invention economical and extremely safer for the users. The Orthopaedic belt can be made for any zone of impact like complete back belt, back - hip belt, upper and lower arm belt, knee belt etc. Future research may involve clinical testing of the product by recruiting participants from varied categories such as sports persons, arthritis patients, and people with chronic pain such as muscle spasms, joint stiffness related issues etc. Pain related questionnaires, similar to the McGill Pain Questionnaires [10] can be designed in order to determine the efficiency of the heat therapy produced by the Orthopaedic belt, by making the participants to score their discomfort level before and after the usage of belt.

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