

DEVELOPMENT PROCESS FOR AN ERGONOMIC PILL CRUSHER
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Nurses use pill crushers to crush pills for patients who have difficulty swallowing. **This task, often performed several hundred times per day, is repetitive in nature and increases the risk of musculoskeletal injury (MSI).** The objective of this paper is to describe the participatory ergonomics approach used to develop a new pill crusher that will reduce ergonomic risk factors and improve crushing capability. Direct observation, interviews, and a focus group (including nurses, care managers and safety professionals) were used to identify risk factors and to develop design requirements and constraints for a new pill crusher prototype. **Identified problems included forceful and repetitive crushing, awkward shoulder and wrist postures, inhalation of powders, and noise.** Conceptual design models and prototypes were developed, tested and evaluated against the new design requirements and constraints.

Key words: design, pill crusher, and healthcare

LE PROCÉDÉ DU DÉVELOPPEMENT D'UNE BROYEUSE DE PILULE ÉRGONOMIQUE

Les infirmières utilisent les broyeuses de pilules pour écraser les médicaments pour les patients qui ont des difficultés avec l'acte d'avalant. Cette tâche, qui est effectuée plusieurs de centaines de fois chaque jour, est répétitive et élève le risque de développer un dégât musculo-squelettique (MSI). L'objectif de ce papier est de décrire le rapprochement de participe ergonomique qui a été utilisé pour développer une broyeuse de pilule qui va réduire les risques ergonomiques et améliorer la capacité d'écraser. L'observation directe, les entrevues, et un groupe de sujet spécifique (compris des infirmières, des directeurs de soins et des professionnels de sûreté) ont été employés avec l'intention d'identifier des facteurs de risque et pour développer les exigences et contraintes pour le dessin de la broyeuse de pilule. Les problèmes qui ont été identifiés incluent l'écrasement puissant et répétitif, les maintiens maladroits des épaules et des poignets, l'inhalation des poudres, et le bruit. Les modèles de dessin et les prototypes ont été développés, examinés et évalués contre les exigences et contraintes pour le dessin nouveaux.

Mots clés: dessin, broyeuse de pilule, soin personnel

INTRODUCTION

As part of the medication delivery system, nurses are required to crush pills for patients who have difficulty swallowing. Medications are prepared and delivered several times per day, often requiring crushing of pills. Pill crushers are typically manual devices, similar in style to a hammer attached to a fixed lever arm. **Repetition, force and awkward postures are associated with pushing down on the lever arm to crush pills. These risk factors have been associated with an increased risk of musculoskeletal injury (MSI),** particularly when they occur simultaneously (1,2,4,6,8,10,11). Signs and symptoms of MSI and complaints regarding pill crushing activities are common in nurses, and are supported by documented time loss claims (9).

Compensation statistics in British Columbia for the three-year period of 1997-1999 (9) revealed 153 total claims involving pill crushers, blister packs, and medical carts (or unspecified carts); however, only six of these claims were a direct result of pill crushing (9). Despite this relatively low incidence of injury, the issue of pill crushing was commonly identified by nurses as problematic.

In response to stakeholder concerns for pill crushing safety, the Occupational Health and Safety Agency for Healthcare (OHSAH) in British Columbia held a two-day workshop with nurses, care managers and safety professionals from across the province to discuss pill crushing problems and to explore initiatives to address these concerns. A key outcome of this workshop was a collaboration between OHSAH and the British Columbia Institute of Technology's (BCIT) Health Technology Research Group to research, design, develop and test a new pill crushing device. The objective of this paper is to describe the use of a participatory ergonomics approach to develop a pill crusher prototype.

METHODS

The design process followed the general model outlined by Mayhew (5), which includes establishing design requirements and constraints, creating conceptual design models, prototyping designs, and testing and evaluating alternative prototypes.

Staff interviews and direct observation were conducted in acute care and long term care facilities to identify task requirements, understand the work environment, and identify risk factors associated with pill crushing.

A workshop was held with stakeholders to verify pill crushing issues and to develop design requirements and constraints. Conceptual design models were developed, and prototypes were subsequently constructed and tested.

RESULTS AND DISCUSSION

Task Analysis

Pill crushing devices are stored and used on top of the working surface of medication carts. Nurses push the medication cart from room to room, preparing and administering medications. The working surface height of most medication carts is in the range of 37" to 43". According to Grandjean (2), this height is suitable for precision tasks such as reading, note taking, pill counting and pill sorting, but not ideal for the more physical task of crushing pills. The height of the medication cart and design of most existing pill crushers result in awkward shoulder and wrist postures when nurses push down on the lever arm.

The majority of pill crushers are mechanical devices that consist of a metal head attached to a lever arm that moves about a fulcrum. Pills are placed between two paper cups to minimize contamination of the crushing head, and are then crushed by the head of the crusher. The lever handle is moved up and down several times until the pills are crushed to the desired grade. Once the pills have been crushed, the top cup is removed from the bottom cup and the powder is mixed with juice or food.

Design Requirements and Constraints

Design requirements and constraints were separated into three categories: functional requirements; performance requirements; and user requirements. Functional requirements describe what the device must be able to accomplish, focusing on the operational capabilities. Performance requirements specify how much or how well the device must be able to perform. The user requirements specify the characteristics of the device that must be compatible with external systems, including the user interface.

Functional requirements included the ability of the device to: 1) crush pills into powder form; 2) control for powder dispersal into the air; 3) prevent cross contamination of different medications; 4) be durable and strong; 5) and be compatible with existing medication carts.

Performance requirements included the ability of the device to: 1) crush pills to the desired grade within 15 seconds; 2) require minimal force to operate; and 3) crush pills quietly.

User requirements included: 1) the device must be easy to operate and use; 2) the device must be easy to clean and maintain; 3) the device must not add tasks/steps to the process; and 4) the device must have a handle diameter that accommodates 90% of female hand lengths (7).

Prototype Development and Testing

Five prototypes were developed and tested against the design requirements.

Prototype 1 was a metal piston housed in a cylindrical case that moved up and down against a metal base. Pills were placed into a paper cup, another cup was placed over the pills, and the cup was inserted into a circular indent in the metal base. The metal piston moved up and down repeatedly against the pills until they were crushed. Testing revealed that this prototype provided inadequate crushing and generated excessive noise when the metal piston came into contact with the metal base.

Prototype 2 was a roller system consisting of three pairs of different sized rollers in series. Pills were placed into a plastic bag and then inserted into the first set of rollers, which fed directly into the second set of rollers and then into the third set of rollers. Each pair of rollers was progressively closer together, with the first set of rollers intended to break up the pills, the second set of rollers intended to grind the pieces into smaller pieces, and the third set of rollers intended to grind the pieces into powder. This prototype was unable to generate adequate force to crush the pills without destroying the bag. The plastic bag also tended to explode as a result of trapped air.

Prototype 3 was an ultrasonic rod and plastic tube that were used to explode pills within a fluid. Pills were placed into a plastic tube and an ultrasonic rod was then inserted into the tube. The ultrasonic frequencies were used to crush the pills into powder. This prototype was at first inadequate at crushing because the pills constantly moved away from the ultrasonic rod, but when a smaller tube was used the pills disintegrated more effectively. However, the ultrasonic rod was expensive to purchase and produced high frequency noise.

Prototype 4 was a disposable rotating metal blade inside a disposable cup that was powered by a Dremel tool. The metal blade was first inserted into the cup, then the pills were placed into the cup and the lid was placed over top. The cup was inserted onto the Dremel tool, which was activated by the pressure of the cup, and the pills were ground into powder. Results of the test revealed that the metal blade effectively crushed pills within seconds, but the pills were often crushed too fine, resulting in powder dispersal into the air. The Dremel tool was loud when in operation and the removable blade presented a safety issue, as well as an additional cost to purchase.

Prototype 5 was an inch diameter screw inserted into a threaded metal cylinder that rotated up and down against a base. The heads of the crusher and the base were made out of plastic dimpled surfaces that gripped the pills as the screw twisted against the base. A small motor activated by a button was used to power the screw. Pills were placed into a paper cup, another cup was placed over the pills, and the cups were inserted into a circular indent in the plastic base. Pushing the

button once caused the screw to slowly twist downwards until it hit the base and then return upwards to the starting position.

Prototype 5 was the only prototype that successfully met all design requirements. Results of the test revealed that the combination of the dimpled surface heads and twisting force effectively crushed the pills into powder. One cycle was sufficient to crush most pills, and two to three cycles was capable of crushing the most difficult pills and pill combinations. However, this prototype had some minor problems that included partial tearing of the paper cups, reduced crushing capability if too many pills were placed into the cups, and high torque against the support structure that held the threaded metal cylinder in place.

Future Testing and Modifications

Minor modifications to Prototype 5 are needed to improve compliance with the design requirements. Future testing has also been scheduled to evaluate the effectiveness of the prototype. A second workshop will be held with nurses, care managers and safety professionals to conduct usability trials. The prototype will then be modified according to instruction from the focus group, and piloted in acute care and long term care facilities. It is expected that both tests will result in additional modifications to the prototype design.

CONCLUSIONS

A comprehensive participatory ergonomics design process that included design requirements, conceptual models, prototypes, testing and evaluation was used to develop a new ergonomic pill crusher for the nursing industry. The process involved the participation and input of nurses, care managers and safety professionals. **This pill crusher will reduce manual repetition and the need for forceful pill crushing, thereby resulting in a reduced risk of injury (MSI) to staff during the medication delivery process.**

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