IPAC-RS Device Working Group
Human factors and the design of inhalation devices

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Topics

- Review of published research into the use of inhalation devices
  - approaches
  - findings

- Overview of human factors engineering (HFE) best practice in inhalation device development
  - introduction to analytical and empirical approaches
  - timing of HFE activities through development

- Review of practice
  - Published research
  - Approach to HFE during development within IPAC-RS members

- What next?
Review of Published Research on Devices *in Use*  
- what can this tell us?

- Approaches taken to human factors and assessing compliance
- Understand how devices are used in the ‘real world’
- Tell us how well we’re doing as device designers
- Give us benchmarks for real world error rates…
- … and guidance on study design
- Studies on marketed/established devices…  
  - explore compliance issues  
  - often include the inhalation manoeuvre  
  - are usually performed by clinicians (sometimes sponsored)  
  - can review use of patient’s own device or experience with new device

Patients’ own device

Dry Powder Inhalers: Factors Associated with Device Misuse  
Siegfried Wieshammer and Jens Dreyhaupt, RDD 2009

- Evaluation of error rates in 4 marketed inhalers: Aerolizer®, Diskus®, HandiHaler®, Turbuhaler®
- Prospectively identified essential handling errors
- Subjects (224) were patients who used own devices

- “Nearly one in three patients (30.9%) used DPIs ineffectively in study of 224 newly referred outpatients”
- “Error rate increased with age, … degree of airway obstruction, … and lack of prior training”  
  - Probability of mis-use estimated to range from 10% to 83%
Handling of Inhaler Devices in Actual Pulmonary Practice: Metered-Dose Inhaler Versus Dry Powder Inhalers
Khassawneh et al; Respiratory Care, 2008

- Prospective observational study of patients using their prescribed device, using simple 3-4 'essential step' check list
- pMDI and three DPIs: Turbuhaler®, Diskus®, and Aerolizer®
- 300 asthma/COPD patients

- “In actual pulmonary clinical practice the majority of patients were unable to use pMDI correctly” (75%)
- “Correct handling of DPI devices was variable” (7% - 43%)

Inhalation technique and variables associated with misuse of conventional metered-dose inhalers and newer dry powder inhalers in experienced adults
Melani et al; Annals of allergy, asthma, and immunology., 2004

- Survey of inhalation technique in ~1,400 patients
- Patients' own device used, including inhalation
- Test Devices: pMDI (n= 1056), Aerolizer® (n= 230), Turbuhaler® (n=524) Diskus® (n=475)

- “24% of patients ... use pMDI poorly”
- “Failure to correctly perform essential steps for reliable lung delivery with the Aerolizer®, Turbohaler® and Diskus® was found in 17%, 23% and 24% of patients, respectively.”
- “There was no difference in most variables correlated with poor inhalation between patients using pMDIs and those using DPIs”
New (to patient) device

Comparison of the Diskus® Inhaler and the Handihaler® Regarding Preference and Ease of Use
Van Der Palen at al; Journal of Aerosol Medicine, 2007

- Determined how many attempts were required for patients to correctly use the inhaler
- Also assessed acceptability of resistance using test pieces
- Subjects (60) were COPD patients with no experience of either device

- “Ease of use was equally good with Diskus® and HandiHaler®”
- “One third (of subjects) inhaled perfectly after reading the instruction leaflet …”
- “… which increased to 85% after one instruction”

New (to patient) device

Handling and Preferences for Available Dry Powder Inhaler Systems by Patients with Asthma and COPD

- Handling and preference assessed for 7 different DPIs
- Subjects (72) were asthma patients with no experience of any of the devices
- Empty devices used, inhalation checked by observation

- % of patients with ‘critical’ handling errors after first use (reading leaflet) ranged from 25% to 72%
- % of patients with ‘critical’ handling errors after second use (instruction) ranged from 8% to 52%
- “Device handling and patient preference are closely correlated”
- “Reduced patients acceptance of a device, being dependent on device handling, may reduce … patients’ compliance”
Do these studies give us a ‘benchmark’?

Reported error rates for patients using their own device:
- Nearly one in three patients (30.9%) used DPIs ineffectively in study of 224 newly referred outpatients
- Failure to correctly perform essential steps for reliable lung delivery with the Aerolizer®, Turbohaler® and Diskus® was found in 17%, 23% and 24% of patients, respectively.

Reported error rates for patients using a new device:
- % of patients with ‘critical’ handling errors after first use (reading leaflet) ranged from 25% to 72%
- % of patients with ‘critical’ handling errors after second use (instruction) ranged from 8% to 52%
- One third of subjects inhaled correctly after reading instruction leaflet
- 85% inhaled correctly after instruction

Published papers give us valuable insights into device use and the complexities of conducting handling studies
- There is a lot of evidence that current devices fall short
  - Although impact of ‘errors’ isn’t always clear – may not affect therapy
- Assessment of inhalation manoeuvre can be problematic …
  - Often assessed through observation
  - Again, clinical significance of ‘poor technique’ not always apparent
- Benchmark seems to be that 1/4 - 1/3 of DPI users use their inhalers ‘incorrectly’ (or not according to the instructions)
- Interesting correlations between acceptance and compliance, age and (non) compliance
  - User acceptance influences compliance
Why are user research and human factors important?

- Design aesthetic
- Usable
- Comfortable
- Mental model
- Safe
- Analytical human factors
- Relevant methods
- Effective in user’s hands
- Easy to use
- User testing
- Usability studies
- Preference studies
- User requirement research
- Co-design
- Functionality
- Meets users’ requirements
- Relevant topics/concepts
- Appealing
- Useful

Meeting the challenge – guidance and theory

- FDA guidance
  - Do it by Design
  - Human Factors Input to Risk Management
- Key standards
  - ISO/IEC 62366
  - ANSI/AAMI HE74 and HE75:2009

HE75: HFE – Design of Medical Devices
- A useful methodology handbook
- Provides guidance on key HFE issues for OINDP:
  - Managing risk of use error
  - Suggested HFE techniques through development
  - How to test usability of devices
- Also a valuable source of information on
  - Human abilities and anthropometry
  - Documentation and packaging
  - Broad range of HFE principles for certain user-interface attributes (controls, displays, alarms etc)
Using ANSI/AAMI HE75:2009 as our methodology handbook

Design Control Activities

- Concept Phase
  - Perform Studies & Analysis
- Design Input
  - Design Requirements
- Design Output
  - Design Specifications
- Verification
  - Test Output Against Input
- Validation
  - Test Against User Needs

Human Factors Activities

- methods to gain insight into users’ needs
- methods to detail & define verifiable design objectives
- methods to explore & challenge potential design solutions
- methods to confirm that design solutions work
- the final confirmation of meeting users’ needs

Some Core HFE Methodology

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Human Factors Activities

- Contextual Inquiry
- Literature Reviews
- Complaints Analysis
- Market Research
- Task Analysis
- User Profiles
- Use Environment
- Heuristic Review
- Risk Analysis
- Useability Objectives
- Prototyping / Simulations
- Iterative Design
- Formative Usability Testing
- Expert Reviews
- Cognitive Walkthroughs
- Summative Usability Testing
- Production Units (or Equivalent)
- Summative Usability Testing
- Field Studies

Figure adapted from AAMI HE75:2009

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Concept Phase Activity
Defining User Requirement Metrics

definition of target metric:

example empirical method:
contextual enquiry

• focused research into the real world use of the intended device:
  – how used?
  – by who?
  – where?
  – when?
  – what current problems exist with similar devices?

purpose: to direct design and engineering from the outset regarding fundamental user requirements

Design Input Activity
HFE as a fundamental Design Input

definition of target metric:

example analytical method:
task analysis

• analysis of the interaction between the user and the intended device
  – how the engineering and design of the device will fit, not conflict, with predictable user expectations

• initial use-related risk assessment
  – based on hazards defined in risk management plan
  – what will define a safe device?

purpose: on the basis of impact on the user, proactively establish fundamental rules for how the device should function, which engineers and designers must work within
Design Output Activity
Usability testing within development

example empirical method:
**formative usability testing**

- observation of real, representative users using prototypes
- selection of competing design approaches
- development of training / instruction designs
- iterative
- provide “opportunities to fail” – it may be important to go back

purpose: to **challenge competing design approaches** and develop understanding of how users interact with device designs in practice

Verification Activity
HFE as part of Risk Management

example analytical method:
**use-related risk analysis**

- the use-related risk equivalent of FMEA – a detailed and exhaustive assessment of the risk associated with use of the device as designed
  - built on the hazard definitions and risk acceptance criteria defined in the project risk management plan
  - e.g. based on a state-space map
  - e.g. including sequences of use-errors that can lead to hazards
  - ideally, including lab-based practical exploration of device performance under variation of user input

purpose: to confirm – by **analysis** - that a **safe device design** has been delivered
Validation Activity
Usability Validation

example empirical method:
**summative usability testing**

- evidence of the usability of your device, achieved through ‘simulated use’
validation study with the final device / instructions for use designs

purpose: to provide a single study that confirms **acceptable usability of the final design** as submitted for approval

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Summary

- Our objective is safe *and* appealing devices

- Human Factors Engineering (HFE) is the relevant discipline
  – HFE a key part of risk management as well as design activities

- HE75 is a good guide

- Best practice will incorporate both analytical and empirical methods
### Review of ‘actual’ practice

- Studies on devices in development/pre-launch…
  - aim to inform the design and design process
  - help to produce attractive, easy-to-use devices
  - help to manage design risk/safety

### Vectura example:
**GyroHaler® user handling studies – actual and planned**

- Concept models
- Moulded prototypes
- Final device

- Time (non-linear scale)

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**Novartis example, with focus on design phases**
(with thanks to Novartis members of Device WG)

**Exploratory study to provide input to industrial design direction at macro level (overall shape and handling position)**

- **Global Patient Use Study (Global)**
- **Small studies with non-patients exploring design direction preferences and evaluation of engineering solutions, for example cap design**

**Block models**

- **Focus Groups**
- **“looks-like, works-like” block models**

**Research/design input**

- **Concept generation & selection**
- **Detailed design & design proving**

**Time (non-linear scale)**

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**Typical ‘formative’ study design (concept phase):**

- **12-24 subjects:**
  - usually patients (i.e. inhaler user)
  - sometimes selected by age/inhaler type etc
- **Broad study objective to inform design process/selection**
- **Should however have specific aim to identify unanticipated use-related hazards as part of risk management process**
- **Stimulus/test material includes concept models, usually as representative of the ‘user experience’ as possible**
- **Specific areas of design can be explored with greater numbers of non-patients**
  - E.g. interpretation of particular features, legibility, grip etc can be explored with larger numbers of non-patients more easily and quickly
- **Inhalation manoeuvre not included**
- **Often includes preference aspect to address ‘do they like it?’ alongside ‘can they use it?’**
Typical 'summative' study design (verification phase):

- 12++ subjects
- Explicitly part of the risk management/device verification process
- Focus on robustness and safe & effective use
- Will form part of an overall picture created from clinical studies, flow rates studies, lab-based device verification testing etc
- Legibility and comprehension of IFU also addressed
- 'Worst case' studies may be used to assess use and robustness in the absence of IFU and instruction
- Study materials likely to be final-form devices/IFU

Devices pre-launch – 2 published examples

A comparison of the efficacy, safety and device handling of Fluticasone Propionate 50µg BD via the Diskus®, Accuhaler® and Diskhaler® inhalers in asthmatic children
Cohen et al; RESPIR. CRIT. CARE MED. 1995
- 4 week safety and efficacy study incorporating device handling and preference
- 267 subjects
- Formed part of clinical development programme

- 77% of Diskus® patients and 71% of Diskhaler® patients were able to use the devices correctly after first instruction
- 81% of Diskus® patients and 51% of Diskhaler® patients found the devices very easy to use
- 70% of patients preferred Diskus®

Characteristics of a capsule based dry powder inhaler, Breezhaler®
Pavkov et al; Current Medical Research & Opinion, 2010
- Brief report on performance characteristics and robustness, based on results from a number of studies
- Studies included PIF assessment, robustness, complaint rate (90,000 devices)

- Patients can achieve the necessary flow rate
- Low number of complaints, no functional device failures
Conclusions

✓ Standards / regulators are capturing best practice and setting expectations
  – Basic approaches are clear
  – But, regulations derive from multiple sources
  – Benchmarks aren’t established

✓ OINDP industry is developing and implementing best practice:
  – As a key part of the risk management process
  – To develop better devices for patients

✓ But we are in the early stages of developing a consistent industry approach
  – Little shared experience so far
  – Situation is comparable to introduction of FMEA 15-20 years ago
  – Interesting comparison with ‘mature’ discussion and awareness of analytical methods

✓ Conferences/discussions such as this will help industry and regulators to move forward, building consistency and confidence