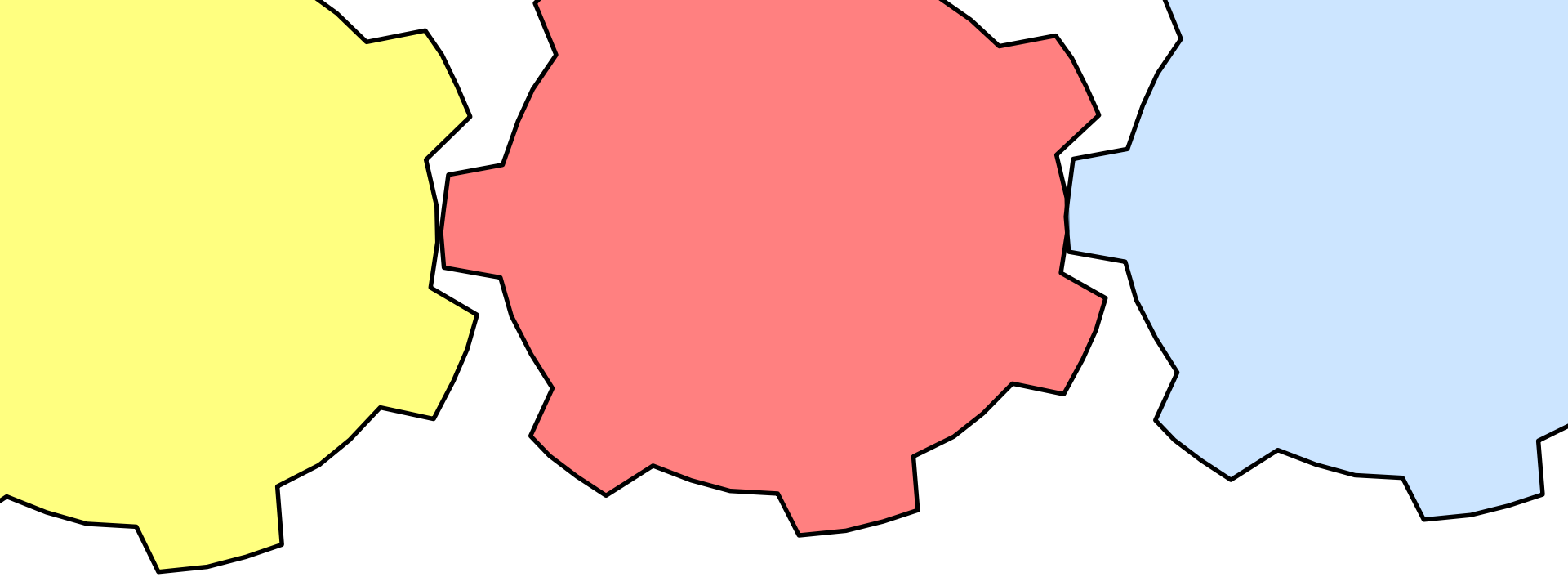
ESCOLA SUPERIOR DE SAÚDE DO ALCOITÃO

SANTA CASA da Misericórdia de Lisboa

ARCADA

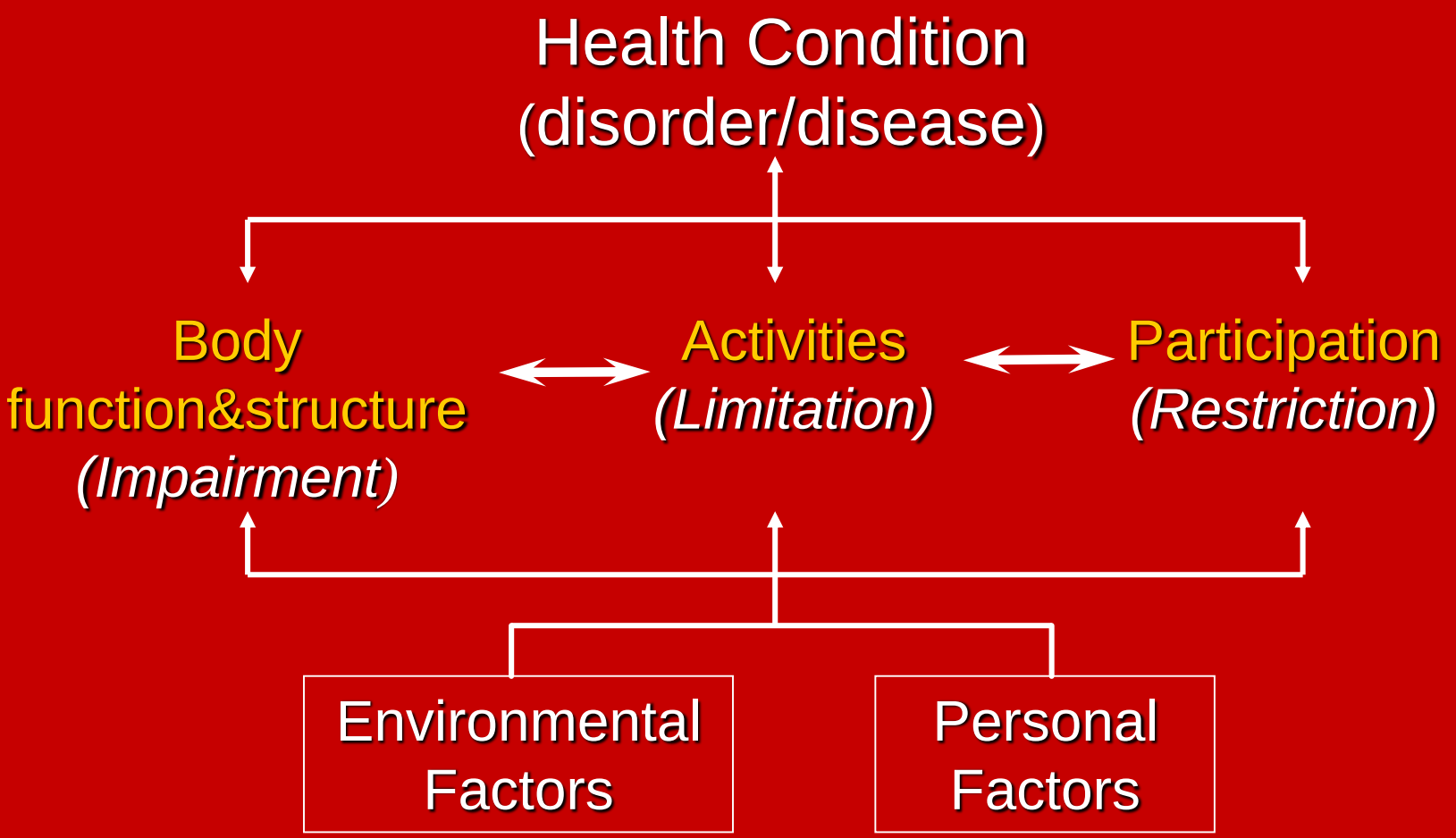
Oxygen transport: a physiologically-based conceptual framework for the practice of cardiopulmonary physiotherapy

António Alves Lopes
Portugal >> Finland | 2013



INTERVENTION FRAMEWORKS

Interaction of Concepts ICF 2001



Contextual Factors

Person

- gender
- age
- other health conditions
- coping style
- social background
- education
- profession
- past experience
- character style

Environment

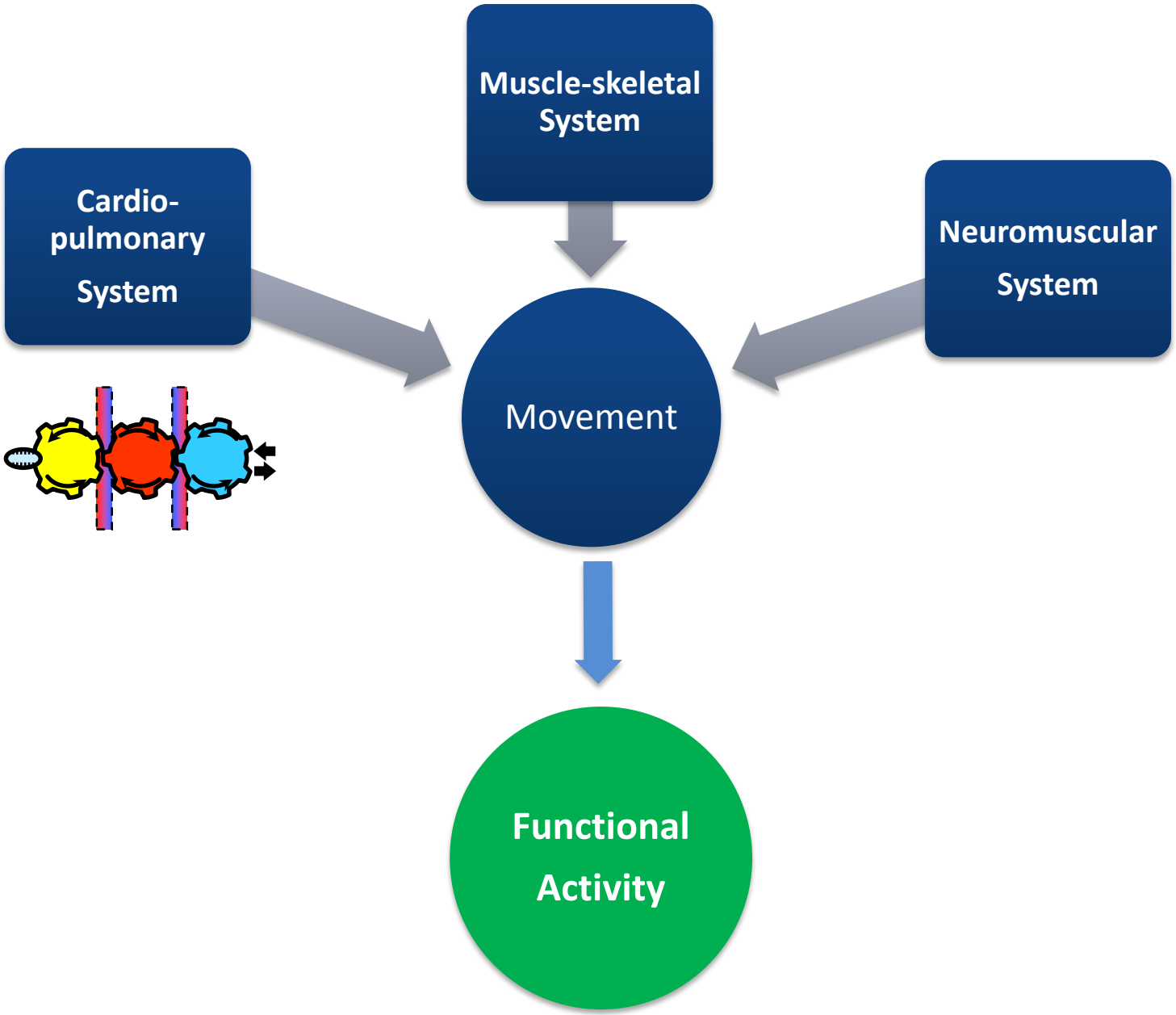
- Products
- Close milieu
- Institutions
- Social Norms
- Culture
- Built-environment
- Political factors
- Nature

ICF Components

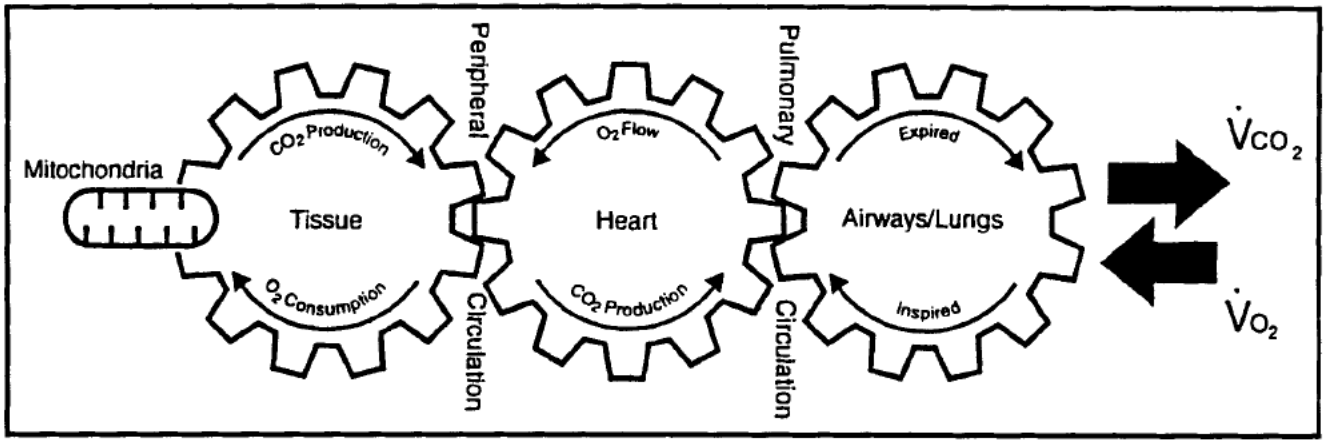
Body Functions & Structures	Activities & Participation	Environmental Factors
 	 	
Functions	*Capacity*	*Barriers*
Structures	*Performance*	*Facilitators*

Body Functions and Structures

Mental functions	Structures of the nervous system
Sensory functions and pain	The eye, ear and related structures
Voice and speech functions	Structures involved in voice and speech
Functions of the cardiovascular, haematological, immunological and respiratory systems	Structures of the cardiovascular, immunological and respiratory systems
Functions of the digestive, metabolic and endocrine systems	Structures related to the digestive, metabolic and endocrine systems
Genitourinary and reproductive functions	Structures related to the genitourinary and reproductive systems
Neuromusculoskeletal and movement-related functions	Structures related to movement
Functions of the skin and related structures	Skin and related structures


Muscle-skeletal System
Cardio-pulmonary System
Neuromuscular System
Movement
Functional Activity

Oxygen Transport System



Delivery or supply of **fully oxygenated blood** to peripheral tissues, the cellular uptake of oxygen, the utilization of oxygen in the tissue, and the return of **partially desaturated blood** to the lungs.

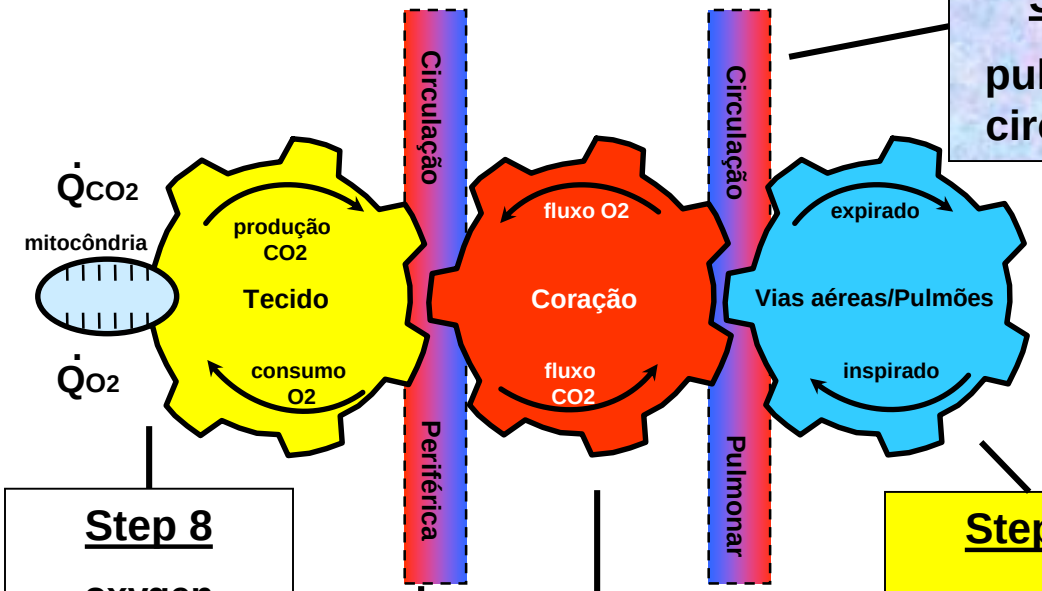
The steps in this system include:

Step 9

Return of CO2 and partially desaturated blood to the lungs

Step 5

pulmonary circulation



Atmosfera

N2,O2,CO2
760 mm Hg
humidade
qualidade ar

Step 8

oxygen extraction and utilization in the muscle and tissues

Step 6

Cardiac Function

Step 2

Airways

Step 3

Lungs

Step 1

the quality of inspired gas

Step 7

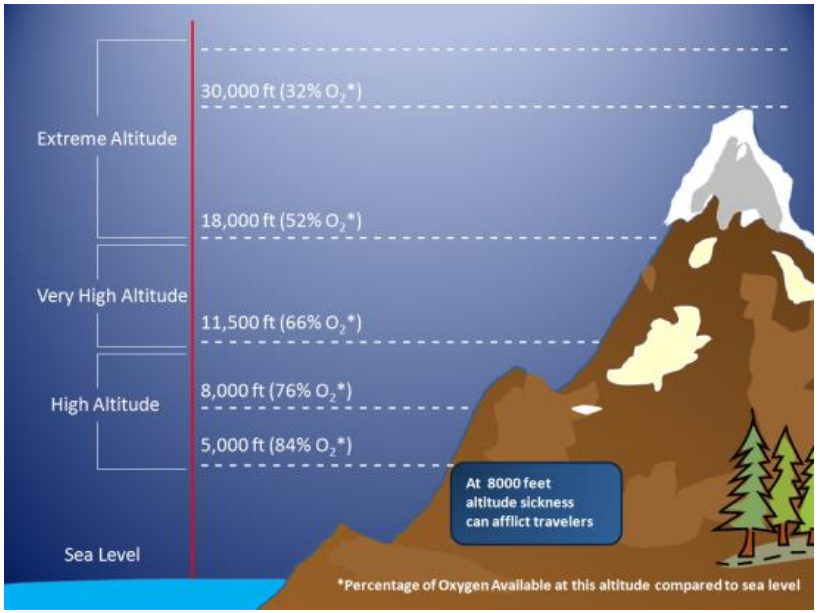
Peripheral circulation

Step 4

diffusion

Step 1: Inspired Oxygen and Quality of the Ambient Air

Atmospheric air consists of 79% nitrogen, 20.97% oxygen, and 0.03% carbon dioxide



- altitude,
- geographical area,
- season,
- population density,
- home and work environment,
- level of ventilation,
- …

Step 2: Airways

Airway structure and function

Airway obstruction and increased resistance to airflow, is caused by multiple factors:

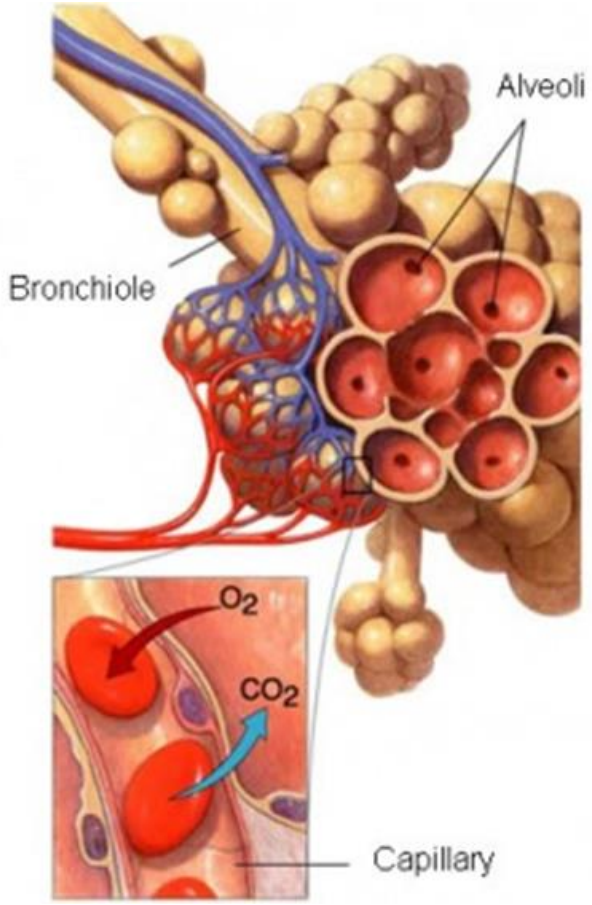
- edema, mucus, foreign objects, calcification, particulate matter, space-occupying lesions, and hyper-reactivity of bronchial smooth muscle.

Step 3: Lungs and Chest Wall

Air entry to the lungs depends on the integrity of :

- Respiratory drive (CNS)
- Respiratory muscles, in particular the diaphragm
- Chest wall (mobility and protection)
- Pleural (negative intrapleural pressure gradient)
- Parenchyma (compliance and elastic recoil)

Step 4: Diffusion



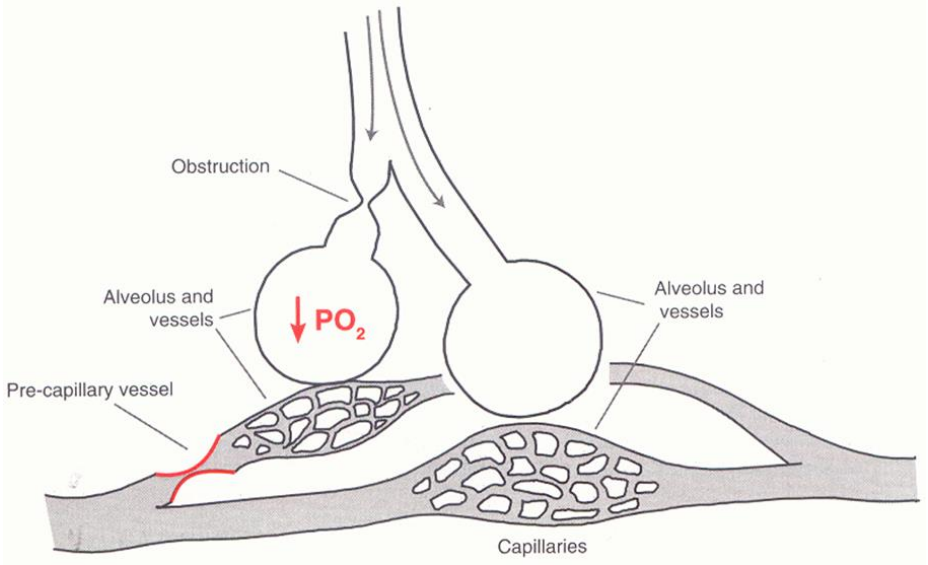
Diffusion of oxygen from the alveolar sacs to the pulmonary arterial circulation depends on:

- area of the alveolar capillary membrane,
- diffusing capacity of the alveolar capillary membrane,
- pulmonary capillary blood volume,
- ventilation-perfusion ratio

(Ganong, 2003).

Step 5: Perfusion

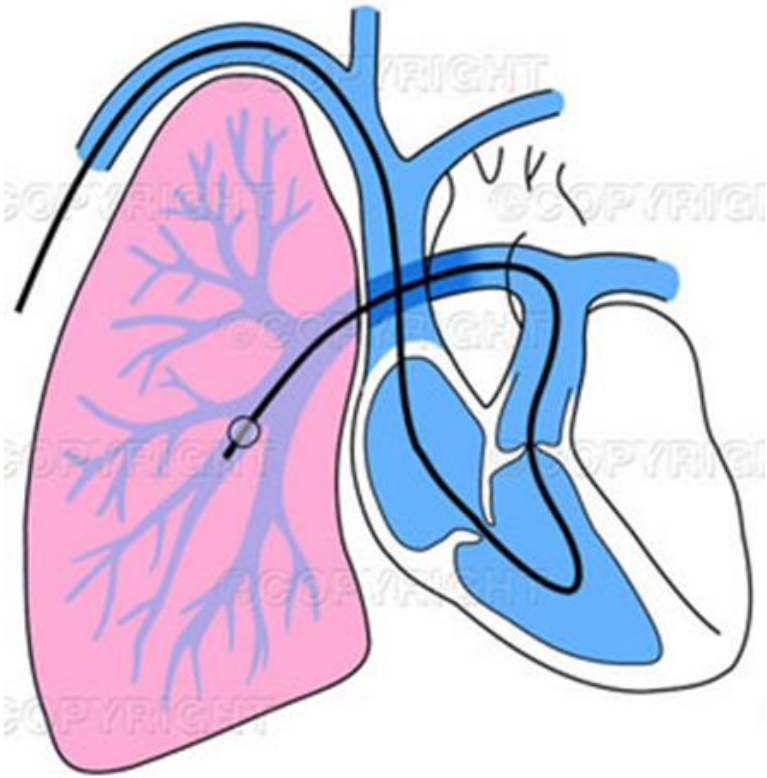
The distribution of blood perfusing the lungs is primarily gravity dependent:



- In the upright lung the bases are better perfused than the apices.
- Ventilation and perfusion matching is optimal in the midzones of the lungs when a person is upright (West, 1985).

Step 6: Myocardial Function

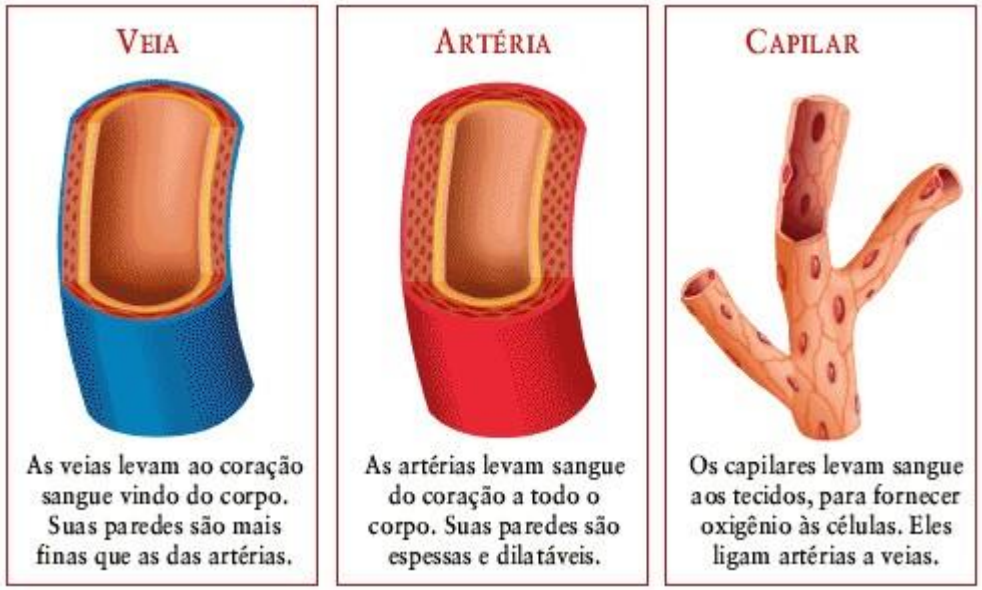
Optimal myocardial function and cardiac output depend on:



- Synchronized coupling of electrical excitation of the heart and mechanical contraction
- The distensibility of the ventricles
- Contractility of the myocardial muscle

Step 7: Peripheral Circulation

Once oxygenated blood is ejected from the heart, the peripheral circulation provides a conduit for supplying this blood to metabolically active tissue

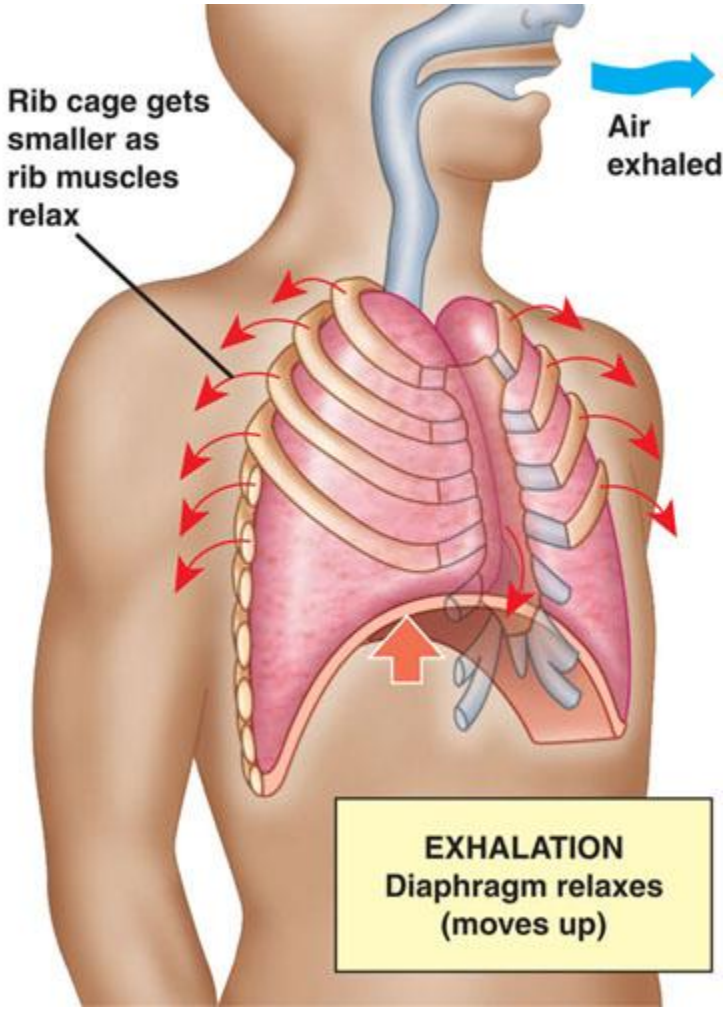


Step 8: Tissue Extraction and Utilization of Oxygen

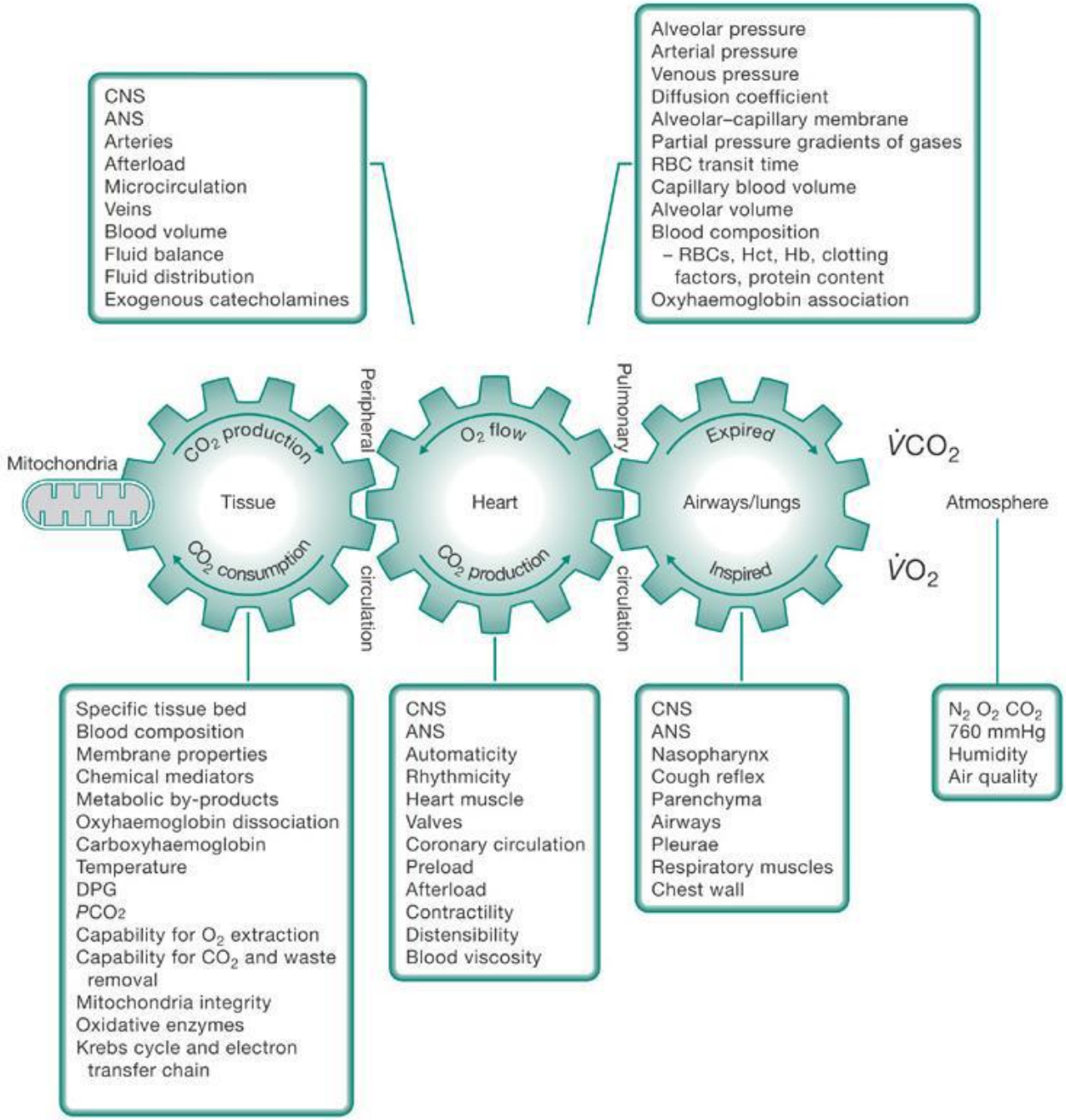
All cells in the body continually use oxygen, which rapidly diffuses out of the circulation and through cell membranes to meet metabolic needs:

- Distance between the capillaries and the cells is variable
- Oxygen pressure (PaO_2)
- Rate of oxygen extraction by the cells is regulated by their oxygen demand

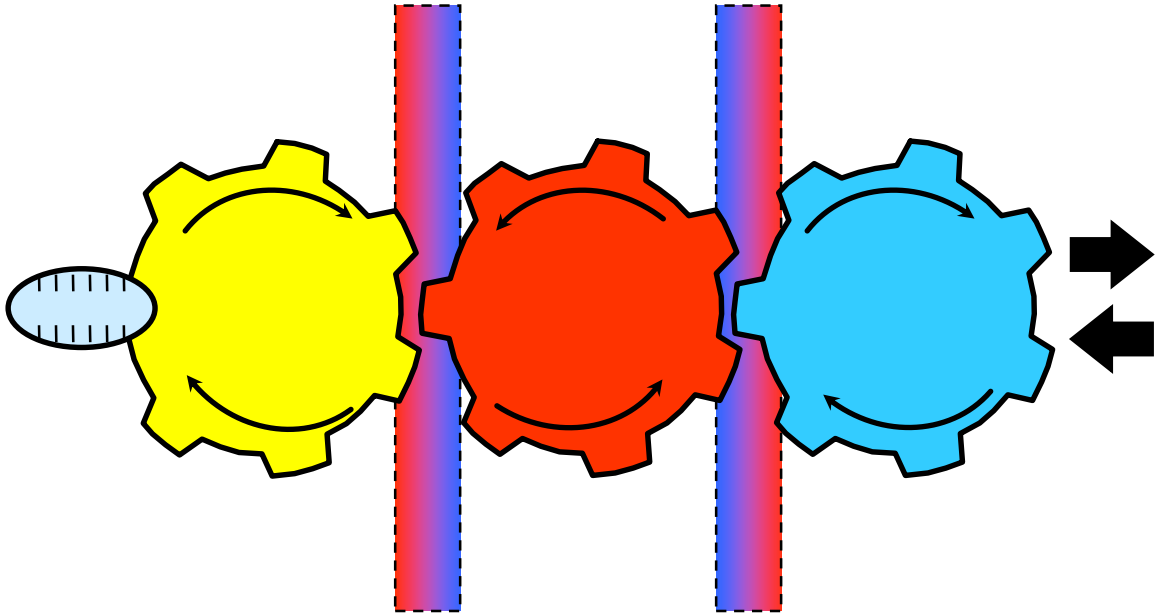
Step 9: Return of Partially Desaturated Blood and Carbon Dioxide to the Lungs



- Partially desaturated blood and carbon dioxide are removed from the cells via the venous circulation to the right side of the heart and lungs;
- Carbon dioxide diffuses across the alveolar capillary membrane and is eliminated from the body via the respiratory system, and the deoxygenated venous blood is reoxygenated;



(Modified from Wasserman et al 1987)



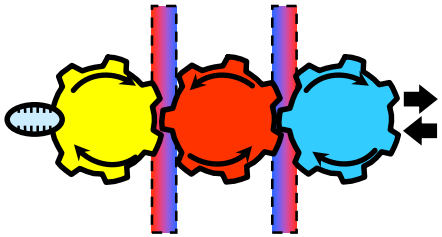
- **No one step is rate limiting; rather each step can individually alter oxygen transport to organ tissues.**
- The system attempts to compensate for impairment at any step.
- In health, this system is acutely responsive to changes in oxygen demand, and changes oxygen delivery correspondingly.

Physical Therapy Process

Interaction of Concepts

Health Condition
(disorder/disease)

Body function&structure *(Impairment)* ⟷ **Activities** *(Limitation)* ⟷ **Participation** *(Restriction)*



Physiotherapy Process

- **Focusing on the STO2 problems**
- **Focusing on the assessment of the STO2**

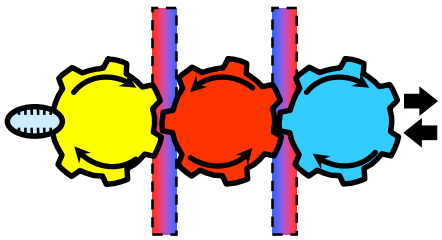
- Enable the physical therapist to identify oxygen transport impairments that compromise functional capacity and contribute to life threatening risk.

Dean & Frownfelter (2012)

Instruments and Measures

Health Condition
(disorder/disease)

Body function/structure
(Impairment)

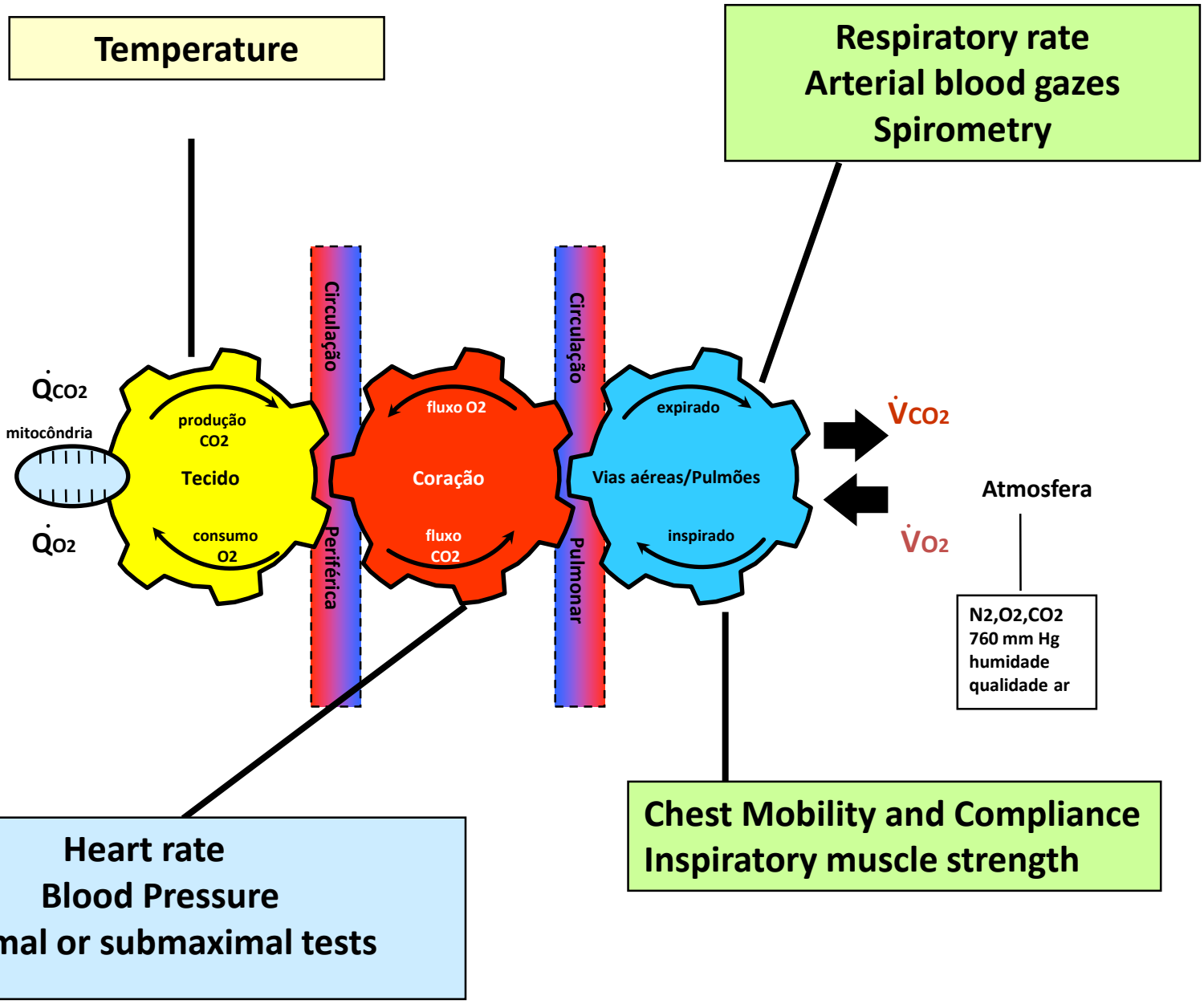


Actividades
(Limitation)

- Borg Scale
- MAHLER Sacale
- 6 and 12 Min walking test
- Shuttle Walking Test

Participação
(Restriction)

- **SGRQ**
- **SF-36**


Temperature
Respiratory rate
Arterial blood gazes
Spirometry
Circulação
Circulação
Periférica
Pulmonar
$\dot{Q}_{CO2}$
mitocôndria
$\dot{Q}_{O2}$
produção CO2
Tecido
consumo O2
fluxo O2
Coração
fluxo CO2
expirado
Vias aéreas/Pulmões
inspirado
$\dot{V}_{CO2}$
$\dot{V}_{O2}$
Atmosfera
N2,O2,CO2
760 mm Hg
humidade
qualidade ar
Heart rate
Blood Pressure
maximal or submaximal tests
Chest Mobility and Compliance
Inspiratory muscle strength

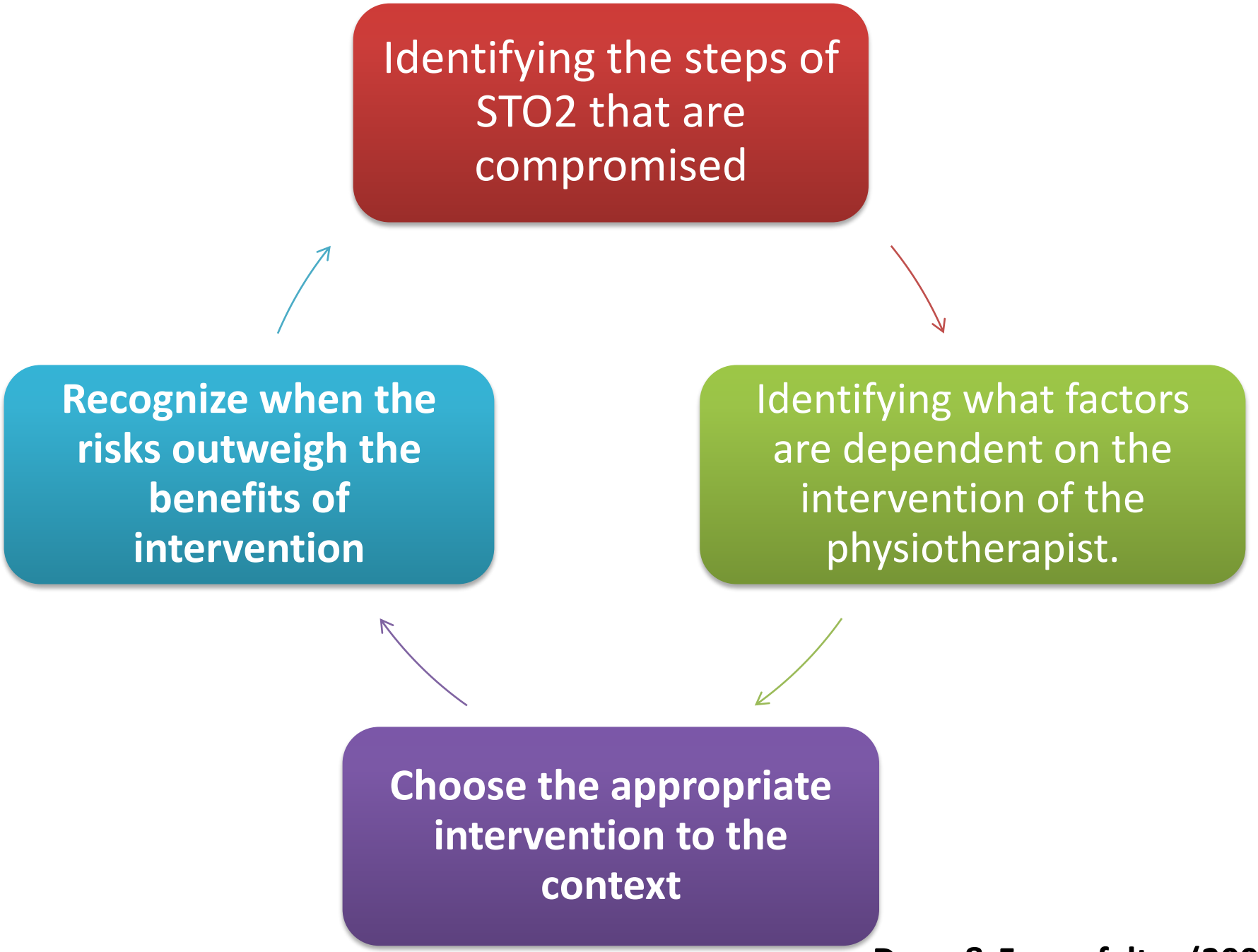
Physiotherapy Process

It is essential that the physical therapist identifies those factors that threaten or contribute to impaired oxygen transport so that the physical therapist can distinguish which impairments are amenable to physical therapy intervention and which are not, or how treatment should be modified.

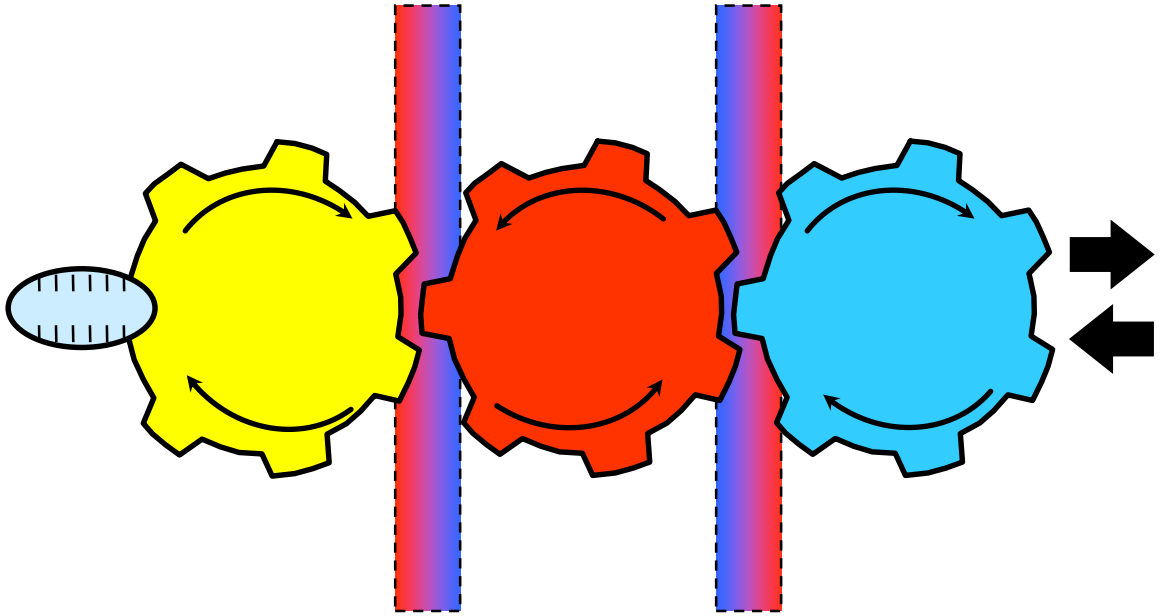
There are 4 categories of factors that threaten or impair oxygen transport:

- **Underlying pathophysiology,**
- **The effects of recumbency and restricted mobility,**
- **External factors directly related to the patient's care**
- **Intrinsic factors directly related to the patient**

Dean & Frownfelter (2006)



Dean & Frownfelter (2006)



- An ability to analyze the contribution or threat of these factors to oxygen transport will ensure that intervention is directed at the underlying impairments, hence, treatment is maximally beneficial and cost effective, and constitutes the least risk and is least costly.

Intervention targets

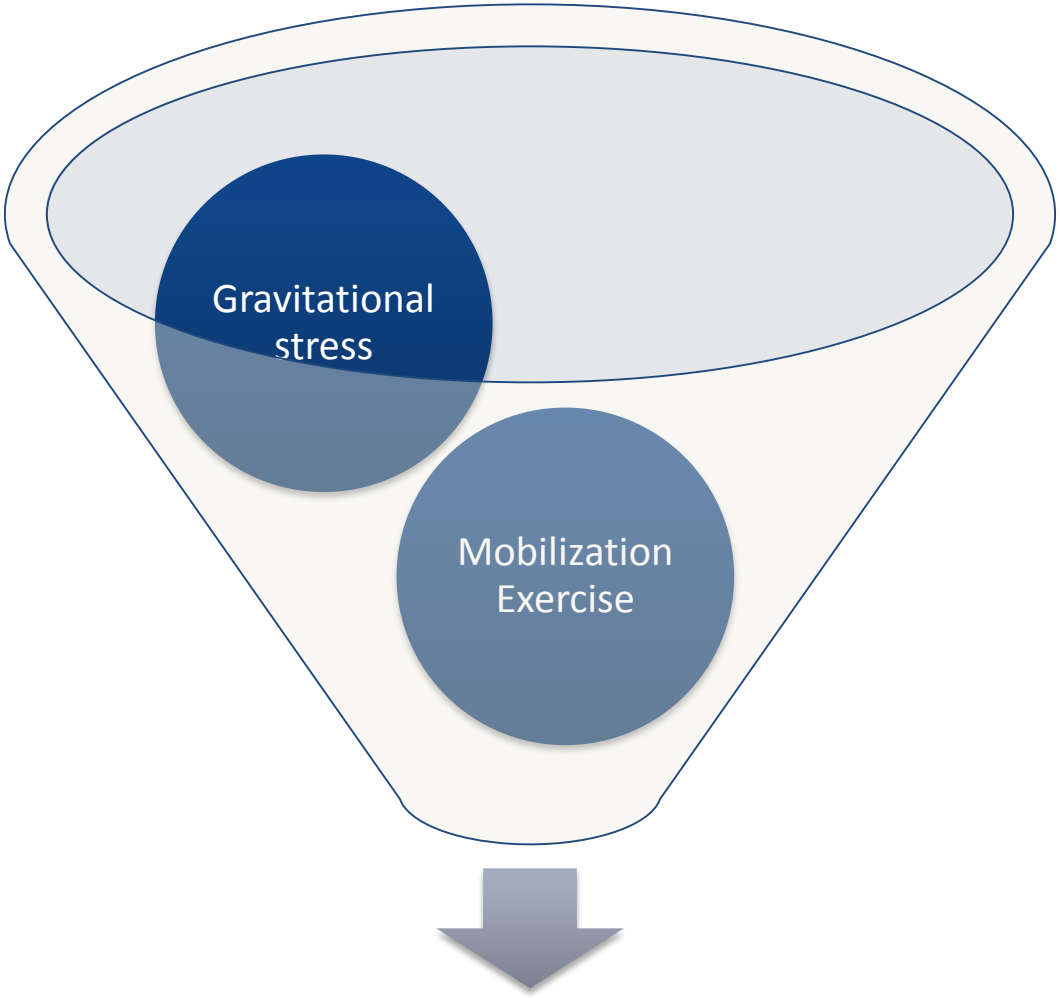
- **Oxygen transport system optimization:**
  - Increase lung volumes and complience
  - Increase of mucus clearence
  - Increase of respiratory muscle strength and chest mobility

Avoid the effects of recumbency and restricted mobility

Promote Daily Living activities

Dean & Frownfelter (2012)

INTERVENTION STRATEGIES



Recumbency and restricted mobility

Consequences off recumbency and restricted mobility

- orthostatic intolerance resulting from the shift of body fluids into the thorax from the extremities and the loss of the stimulus of gravity needed to maintain hemodynamic status in the upright position;
- loss of muscle strength;
- monotonous tidal ventilation
- airway closure, atelectasis, secretion retention
- interstitial fluid accumulation

1 º Premise

The position of optimal physiological function is being upright and moving

2 º Premise

“The best stimulation is one that enhances the oxygen-carrying capacity of the individual and produces the greatest adjustment without causing damage.”

Dean (2012)

Dean's Hierarchy for Treatment of Patients With Impaired Oxygen Transport

- Mobilization and Exercise
- Body Positioning
- Breathing Control Maneuvers
- Coughing Maneuvers
- Relaxation and Energy Conservation Interventions
- ROM Exercises (Cardiopulmonary Indications)
- Manual Techniques
- Suctioning

Dean & Frownfelter (2006)

Mobilization and Exercise

In the context of Cardiopulmonar Physiotherapy the Mobilization refers to a low-intensity exercise

Goal: To elicit an exercise stimulus that addresses one of the three effects on the various steps in the oxygen transport pathway, or some combination:

A. **Acute effects**
B. **Long-term effects**
C. **Preventative effects**

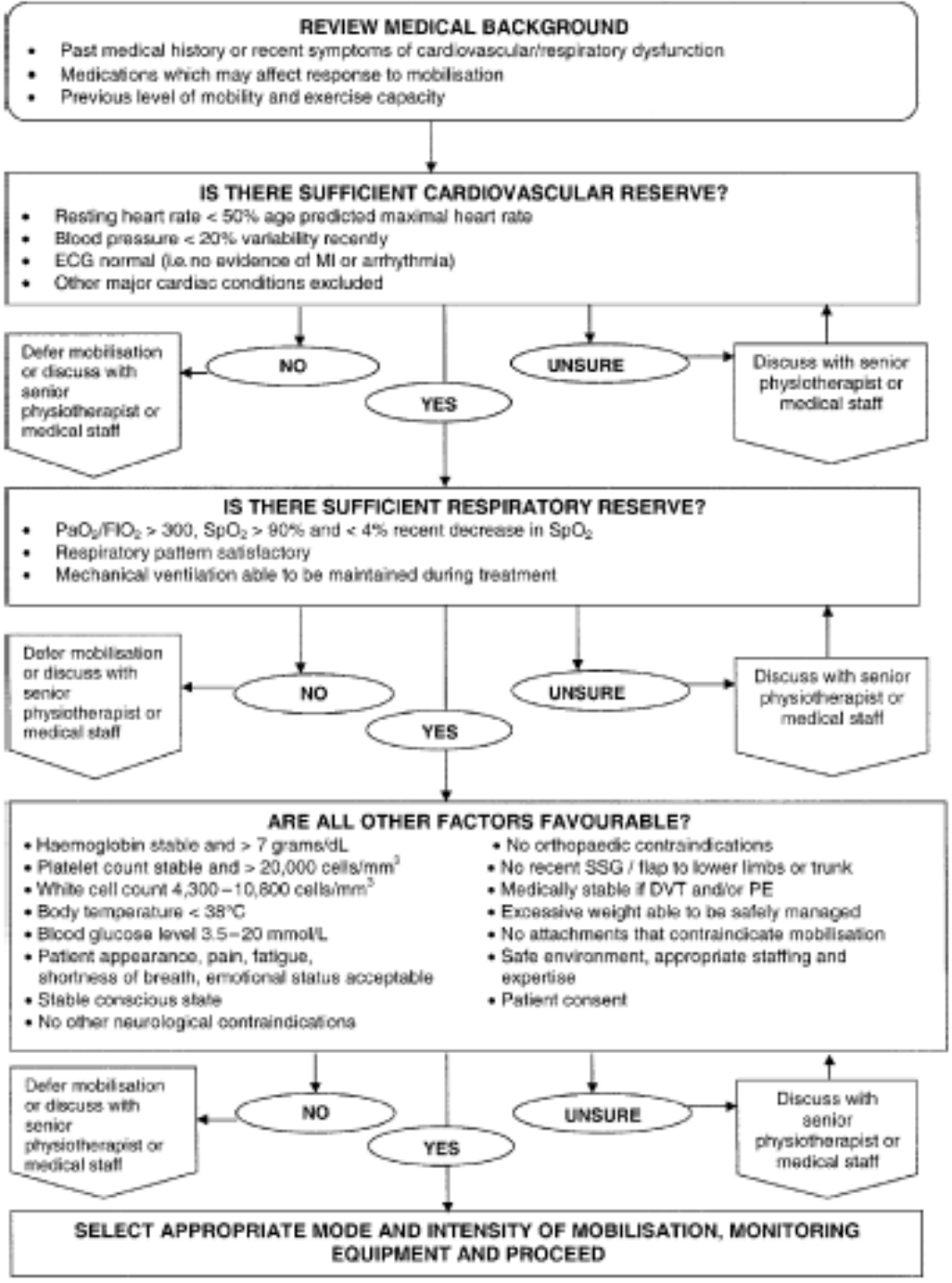


Fig. 1 Overview of safety issues prior to mobilizing acutely ill in-patients (from Stiller and Phillips, 2003).

The safety of mobilisation and its effect on haemodynamic and respiratory status of intensive care patients

Kathy Stiller,
Anna C. Phillips
Paul Lambert

Physiotherapy Theory and Practice, 20, 2004

Body Positioning

Positioning refers to the manipulation of the effect of gravity on cardiovascular and cardiopulmonary functions in order to optimize the transport of oxygen.

Dean (1996)

Body Positioning

Goal: To elicit a gravitational stimulus that simulates being upright and moving as much as possible (ie, active, active assisted, or passive)

•Hemodynamic effects related to fluid shifts;
• Cardiopulmonary effects on ventilation and its distribution, perfusion, ventilation, and perfusion matching and gas exchange;

Dean (2006)

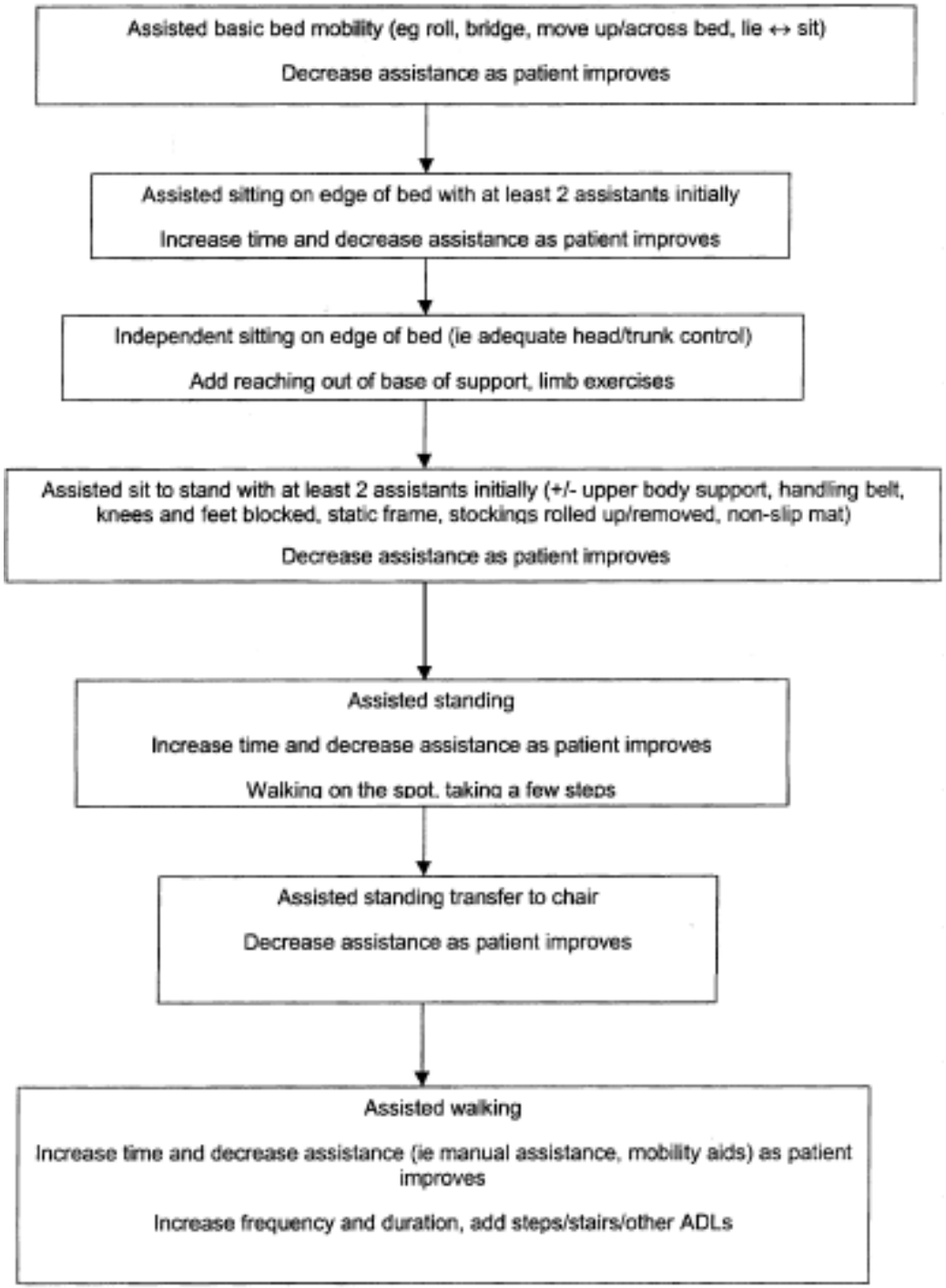
Effect -dependent response

Prescribed

Body Positioning

Rotine Body Positioning

Time -dependent response



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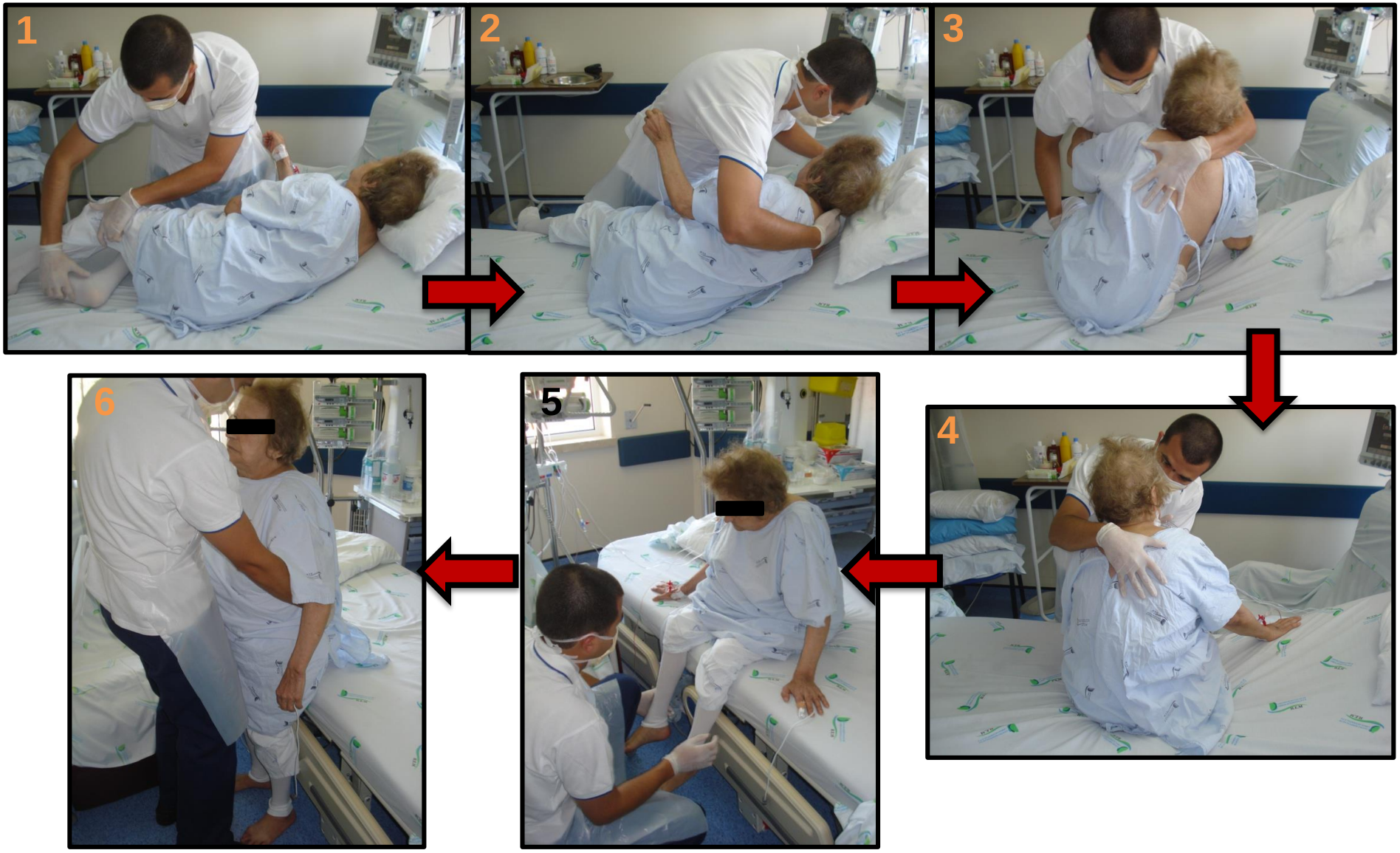


A

B

C

D

E

F

Breathing Control Maneuvers

Goal: To augment alveolar ventilation, faciliate mucociliary transport, and stimulate coughing

A. Coordinated breathing with activity and exercise

B. Spontaneous eucapnic hyperventilation

C. Maximal tidal breaths and movement in three dimensions

D. Sustained maximal inspiration

E. Pursed lip breathing to end-tidal expiration

F. Incentive spirometry

Coughing Maneuvers

Goal: To facilitate mucociliary clearance with the least effect on dynamic airway compression and adverse cardiovascular effects:

A. Active and spontaneous cough with closed glottis
B. Active assist (self-supported or by other)
C. Modified coughing interventions with open glottis (eg, forced expiratory technique, huff)

Relaxation and Energy Conservation Interventions

Goal: To minimize the work of breathing, of the heart, and oxygen demand overall

A. Relaxation procedures at rest and during activity

B. Energy conservation (ie, balance of activity to rest, performing activities in an energy-efficient manner, improved movement economy during activity)

C. Pain control interventions

ROM Exercises (Cardiopulmonary Indications)

Goal: To stimulate alveolar ventilation and alter its distribution

A. Active

B. Assisted active

C. Passive

Manual Techniques

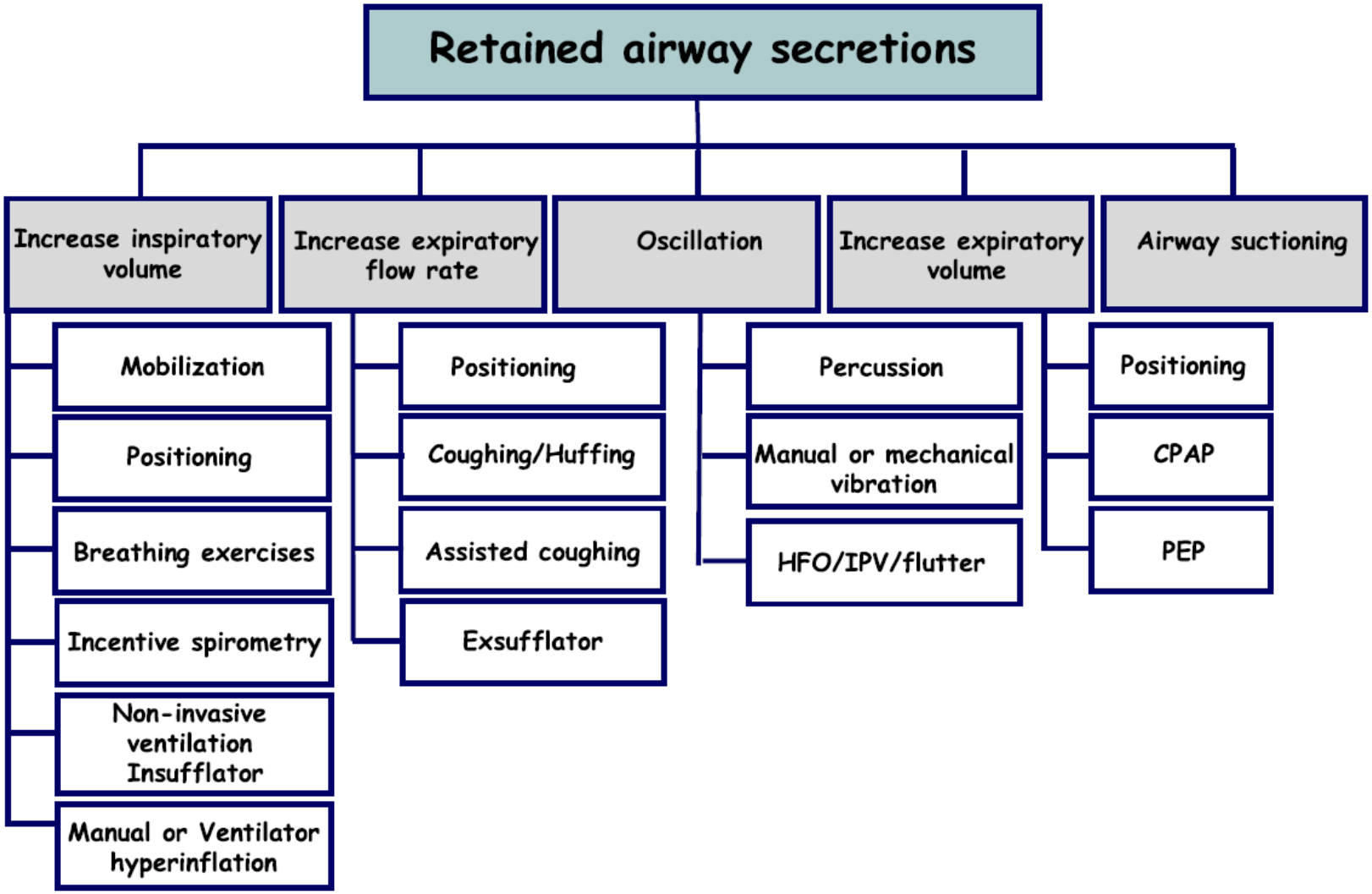
Goal: To facilitate airway clearance in conjunction with specific body positioning:

A. Autogenic drainage

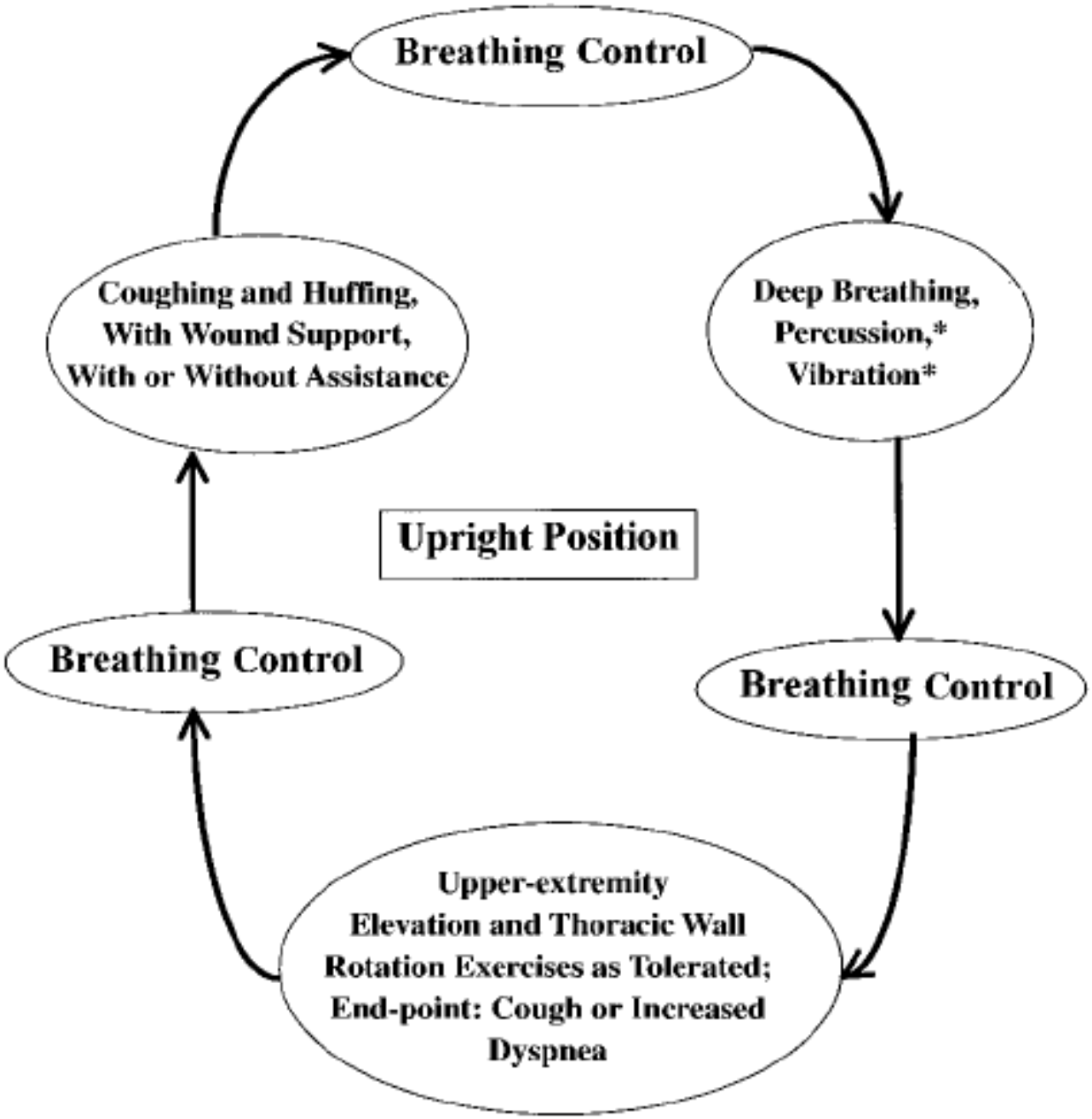
B. Manual percussion ???

C. Shaking and vibration ???

D. Deep breathing and coughing



(Gosselink et al., 2008)


Breathing Control
Deep Breathing, Percussion,* Vibration*
Breathing Control
Upper-extremity Elevation and Thoracic Wall Rotation Exercises as Tolerated; End-point: Cough or Increased Dyspnea
Breathing Control
Coughing and Huffing, With Wound Support, With or Without Assistance
Upright Position

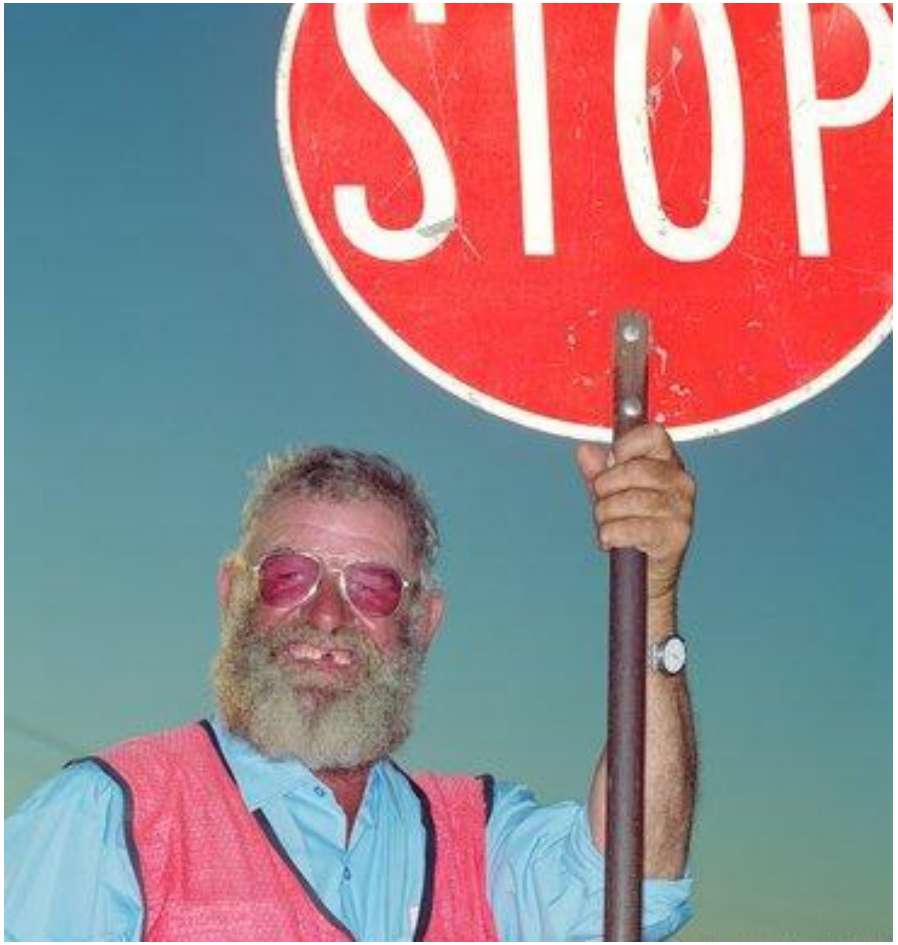
General Guidelines

- **Set the duration of the intervention based on the patient's response (changes in the measures and indices of STO2) instead of in time.**
- **Repeat interventions as many times as possible based on the beneficial effects and tolerance of the patient.**
- **Increase the intensity of the stimulus Mob / Exer. and duration of the operation or both, depending on where the patient's ability to maintain an optimum transport of oxygen and maintenance of variables monitorable pre-defined within the margin of safety.**

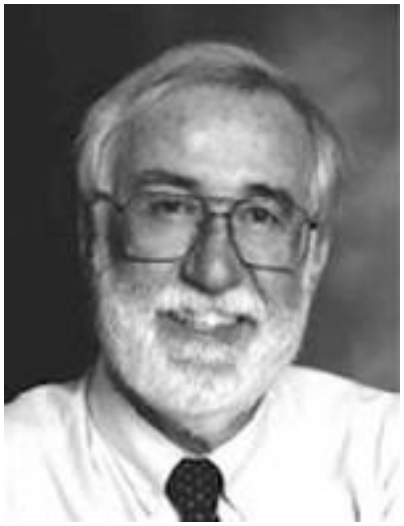
“Everybody lies. You gonna trust me? I lie about everything.”

House M.D.

What is the evidence of these interventions?



Evidence based practice



Evidence based practice is using best *research evidence* available along with *clinical expertise* and *patient values* to inform decisions regarding clinical practice.

(Sackett 1998, 2000)

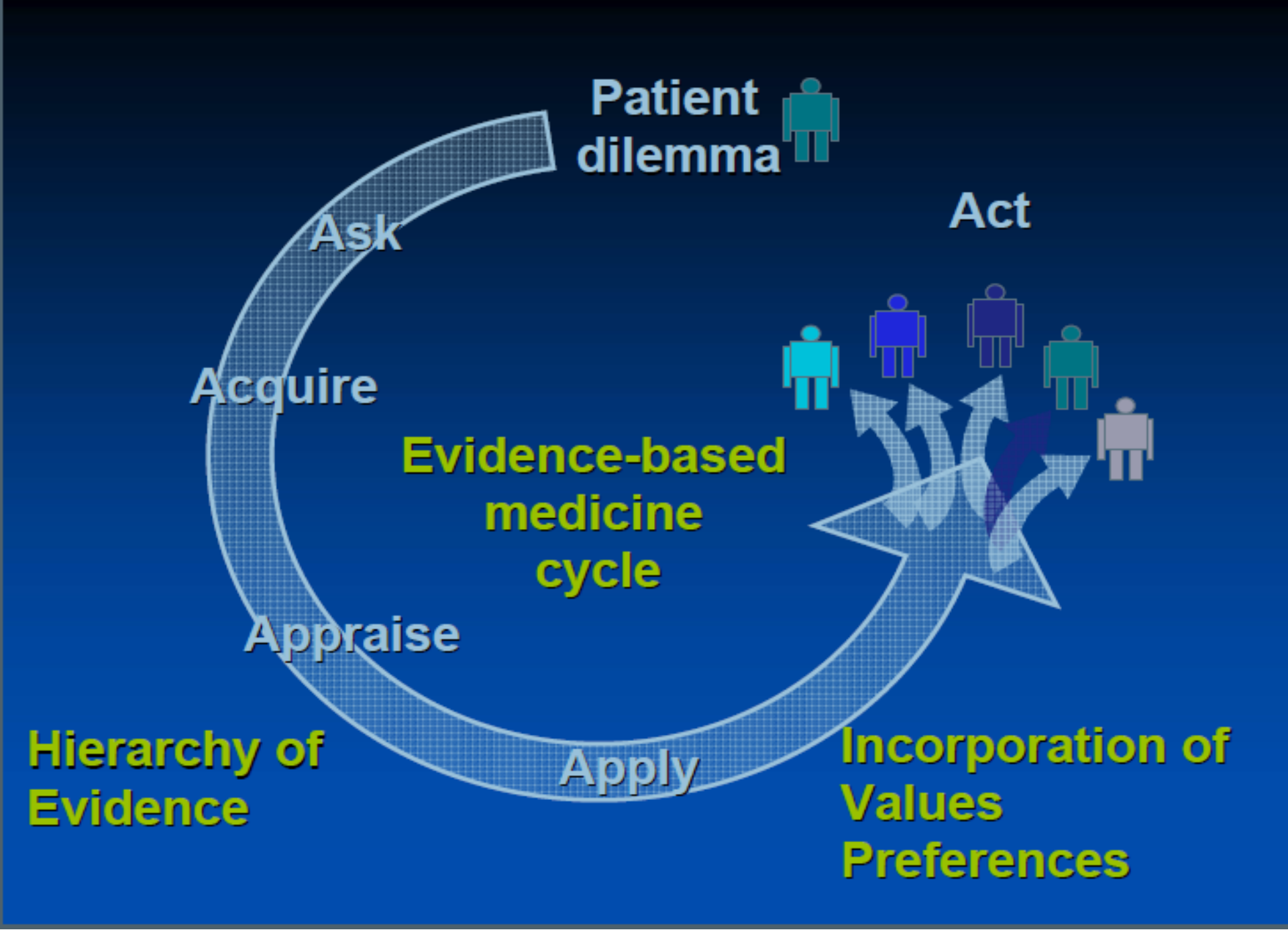
The Importance of Evidence-based Practice…

The evidence-based practice drive has had a significant positive impact on the physiotherapy profession.

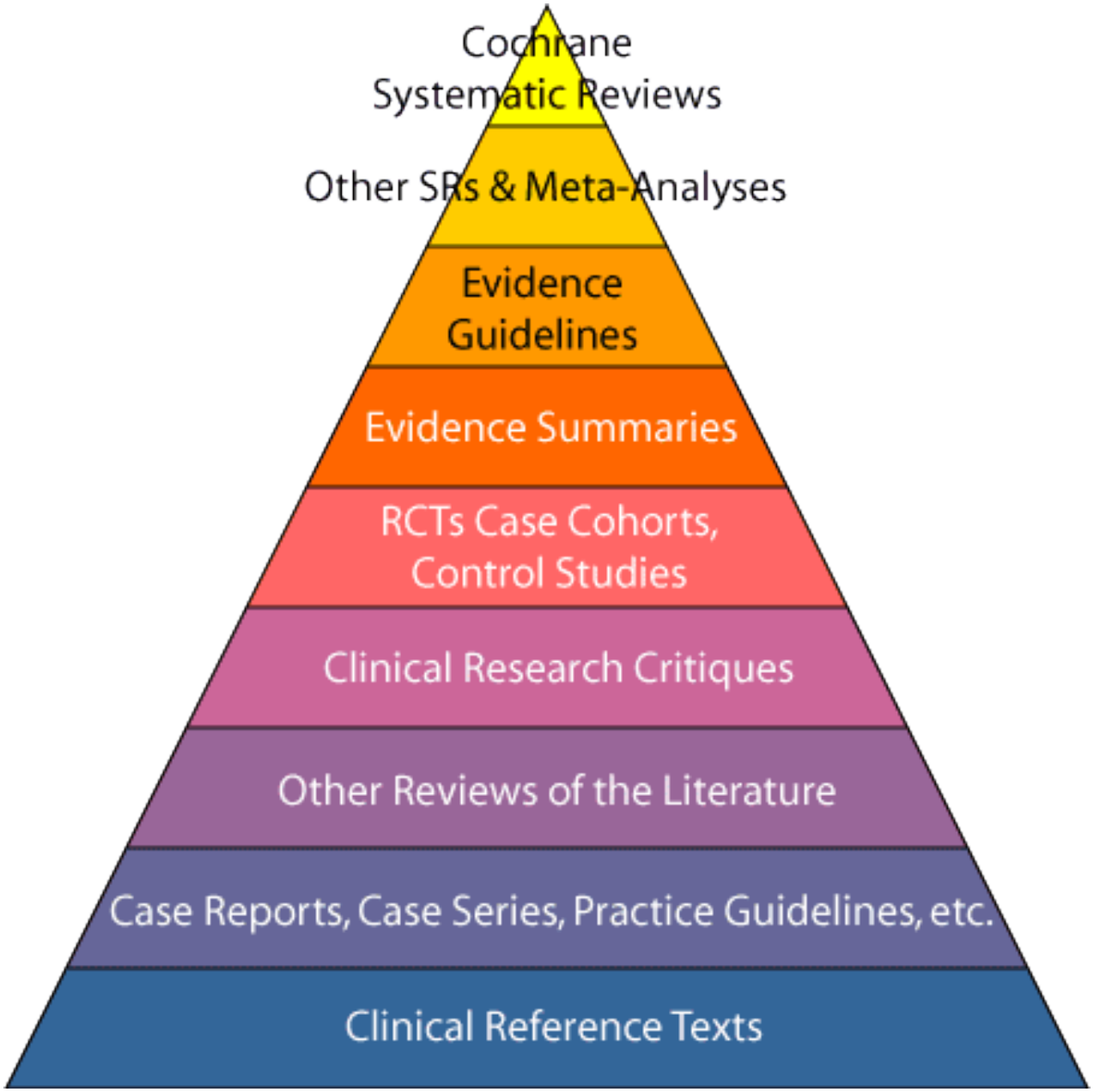
Mark Jones (2006)

World Confederation for Physical Therapy

The World Confederation for Physical Therapy (WCPT) **believes that physical therapists have a duty and responsibility to use evidence to inform practice** and to ensure that the management of patients/clients, their carers and communities is based on the best available evidence.



Guyatt & Sheri Keitz (2008)


Cochrane
Systematic Reviews
Other SRs & Meta-Analyses
Evidence
Guidelines
Evidence Summaries
RCTs Case Cohorts,
Control Studies
Clinical Research Critiques
Other Reviews of the Literature
Case Reports, Case Series, Practice Guidelines, etc.
Clinical Reference Texts

CHEST®

Official publication of the American College of Chest Physicians

Physiotherapy in Intensive Care*

Kathy Stiller

Chest 2000;118;1801-1813
DOI 10.1378/chest.118.6.1801

Table 1—*Summary of Evidence and Evidence-Based Recommendations for Physiotherapy in the ICU*

Strong evidence that:

- Physiotherapy is the treatment of choice for patients with acute lobar atelectasis
- Prone positioning improves oxygenation for some patients with severe acute respiratory failure or ARDS
- Positioning in side lying (affected lung uppermost) improves oxygenation for some patients with unilateral lung disease
- Hemodynamic status should be monitored during physiotherapy to detect any deleterious side effects of treatment
- Sedation before physiotherapy will decrease or prevent adverse hemodynamic or metabolic responses
- Preoxygenation, sedation, and reassurance are necessary before suction to avoid suction-induced hypoxemia
- Continuous rotational therapy decreases the incidence of pulmonary complications

Moderate evidence that:

Multimodality physiotherapy has a short-lived beneficial effect on respiratory function

MH may have a short-lived beneficial effect on respiratory function, but hemodynamic status, airway pressure, or VT should be monitored to detect any deleterious side effects of treatment

ICP and CPP should be monitored on appropriate patients during physiotherapy to detect any deleterious side effects of treatment

Very limited or no evidence that:

Routine physiotherapy in addition to nursing care prevents pulmonary complications commonly found in ICU patients

Physiotherapy is effective in the treatment of pulmonary conditions commonly found in ICU patients (with the exception of acute lobar atelectasis)

Physiotherapy facilitates weaning, decreases length of stay in the ICU or hospital, and reduces mortality or morbidity

Positioning (with the exception of examples cited above), percussion, vibrations, suction, or mobilization are effective components of physiotherapy for ICU patients

Limb exercises prevent loss of joint range or soft-tissue length, or improve muscle strength and function, for ICU patients

CHEST

Original Research

CRITICAL CARE

Physiotherapy in Intensive Care

An Updated Systematic Review

Kathy Stiller, PhD

Background: **Although physiotherapy is frequently provided to patients in the ICU, its role has been questioned. The purpose of this systematic literature review, an update of one published in 2000, was to examine the evidence concerning the effectiveness of physiotherapy for adult, intubated patients who are mechanically ventilated in the ICU.**

Methods: **The main literature search was undertaken on PubMed, with secondary searches of MEDLINE, CINAHL, Embase, the Cochrane Library, and the Physiotherapy Evidence Database. Only papers published from 1999 were included. No limitations were placed on study design, intervention type, or outcomes of clinical studies; nonsystematic reviews were excluded. Items were checked for relevance and data extracted from included studies. Marked heterogeneity of design precluded statistical pooling of results and led to a descriptive review.**

Results: **Fifty-five clinical and 30 nonclinical studies were reviewed. The evidence from randomized controlled trials evaluating the effectiveness of routine multimodality respiratory physiotherapy is conflicting. Physiotherapy that comprises early progressive mobilization has been shown to be feasible and safe, with data from randomized controlled trials demonstrating that it can improve function and shorten ICU and hospital length of stay.**

Conclusions: **Available new evidence, published since 1999, suggests that physiotherapy intervention that comprises early progressive mobilization is beneficial for adult patients in the ICU in terms of its positive effect on functional ability and its potential to reduce ICU and hospital length of stay. These new findings suggest that early progressive mobilization should be implemented as a matter of priority in all adult ICUs and an area of clinical focus for ICU physiotherapists.**

CHEST 2013; 144(3):825–847

Abbreviations: IMT = inspiratory muscle training; LOS = length of stay; MH = manual hyperinflation; NMES = neuromuscular electrical stimulation; RCT = randomized controlled/comparative trial; VAP = ventilator-associated pneumonia; VH = ventilator hyperinflation

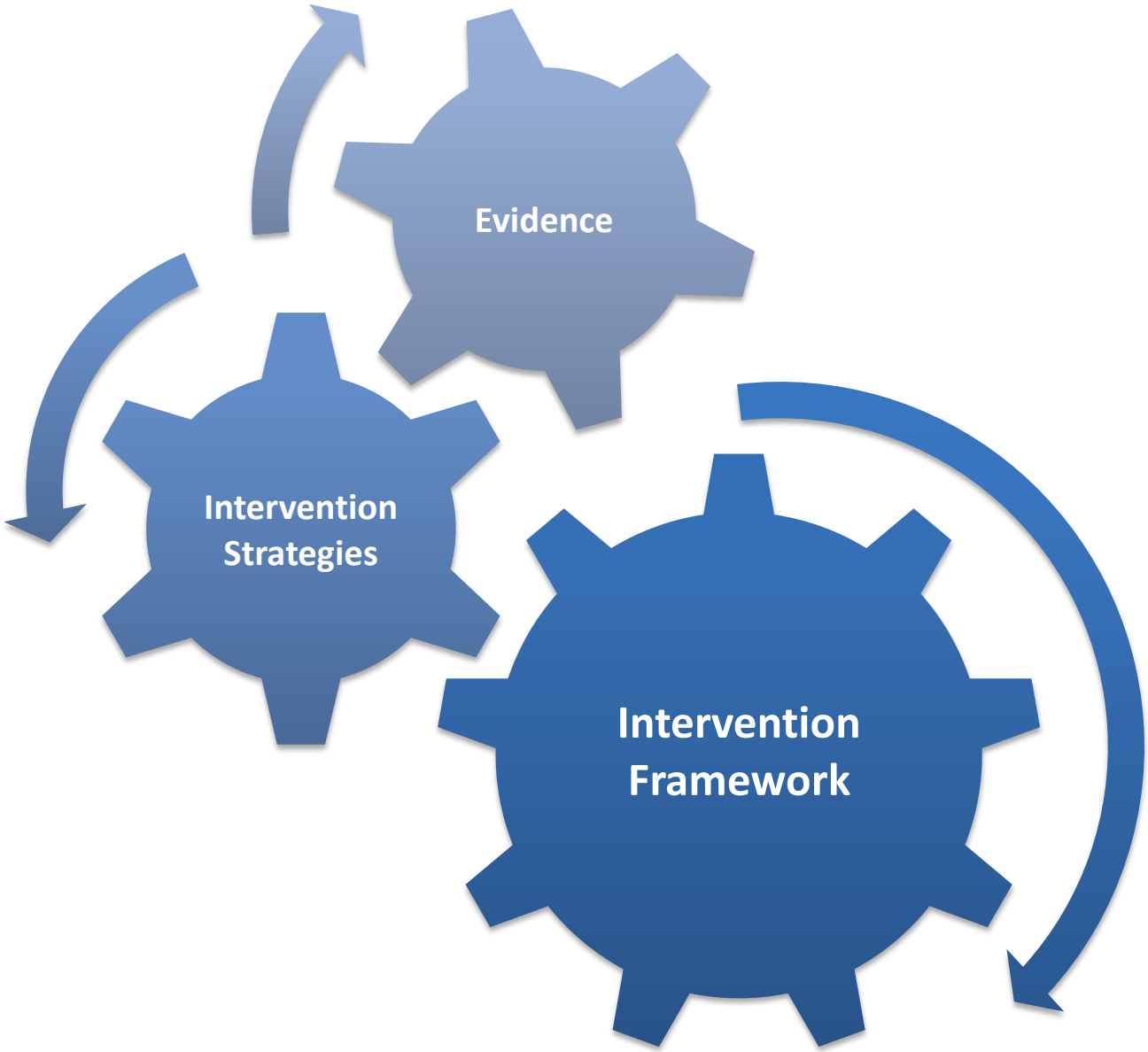
Main Conclusions…

- In summary, the evidence concerning the efficacy of routine multimodality respiratory physiotherapy for adult, intubated patients receiving mechanical ventilation remains unclear.

- There is strong, evidence published since the review in 2000 showing that **physiotherapy intervention focusing on early progressive mobilization is feasible and safe, and results in significant functional benefits**

- evidence confirms the role of the physiotherapist in ICU and highlights that early progressive mobilization is an effective area of physiotherapy clinical practice for adult, intubated, mechanically ventilated patients.

- Further research to confirm the efficacy of early progressive mobilization is required, in particular to determine the optimal “dosage” in terms of its most effective components, intensity, duration, and frequency


Evidence
Intervention Strategies
Intervention Framework

ESCOLA SUPERIOR DE SAÚDE DO ALCOITÃO

ARCADA

SANTA CASA da Misericórdia de Lisboa

Oxygen transport: a physiologically-based conceptual framework for the practice of cardiopulmonary physiotherapy

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http://goo.gl/OeD5Z6