PHYSIOLOGICAL RESPONSES TO THE USE OF UPPER LIMB EXOSKELETON DURING HANDLING TASKS

Consequences on Work Organization ?

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Context

Exoskeletons…

Various forms and applications

1968

Hardiman

2017

Gopura et al, 2015

Military applications

Medical/Rehabilitation applications

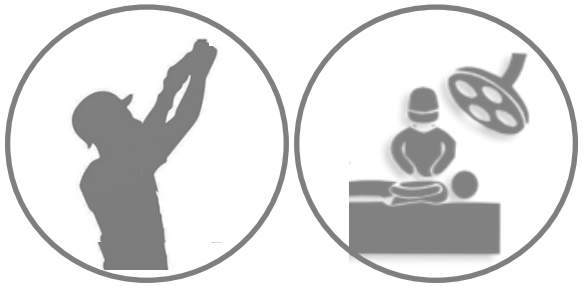
Occupational applications

Exoskeletons…

… in order to prevent MSD ?

… by reducing biomechanical strains …

Limits of modern technology, automation, and work-related interventions



Awkward postures

Manual handling tasks

Focus on low back pain and shoulder MSD

Handling tasks

Bos et al., 2014

Back exoskeletons

Bos et al., 2014

Upper limb exoskeletons

Available

Cost-effective

Previous studies ?

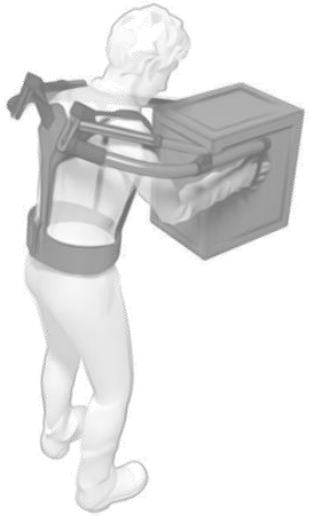
Impact of exoskeletons on physiological workload

Previous studies on handling tasks

HANDLING TASKS

Back exoskeletons

Upper limb exoskeletons



Benefits

Lumbar muscles activity

Abdoli Eramaki et al., 2006 / 2008
Bosch et al., 2016

Lumbar muscles fatigue

Godwin et al., 2009
Lotz et al., 2009
Bosch et al., 2016

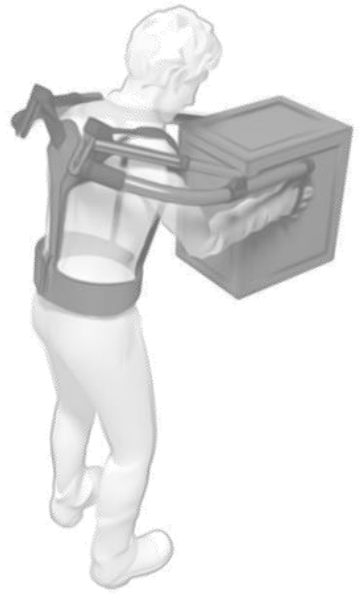
Lumbar spine internal forces

Abdoli Eramaki et al., 2007

Lack of information

About upper limb exoskeleton ?

Only during overhead works



Upper limb exoskeletons

Benefits

Disadvantages ?

Shoulder muscles activity
Rasheidi et al. 2014

Joints torque
Sylla et al., 2014

Perceived exertion (shoulder)
Rasheidi et al. 2014
Sylla et al., 2014

Lumbar muscles activity
Rasheidi et al. 2014

Postural changes
Sylla et al., 2014

Perceived exertion (back)
Rasheidi et al. 2014

Objective of the present study

During manual handling tasks

Upper limb exoskeletons

HANDLING TASKS

Shoulder flexor and extensor muscles activity ?

Postural muscles activity ?

Postural balance ?

Cardiovascular responses ?

Experimental Protocol

Paradigm

EXO versus FREE

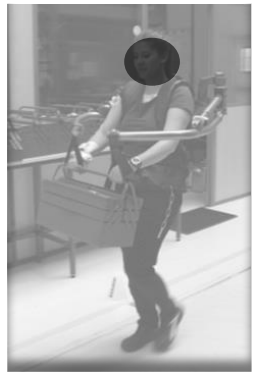
8 participants :
- 4 men
- 4 women
- Trained to the use of EXO
  (4 sessions, ~ 97 min)

EXO

FREE

Lifting task (LIFT)
- Sagittal plane
- Imposed rate (10 c/ min, during 3min)
- 9 kg (men) / 5 kg (women) = assistance

Unstacking / Stacking task (STACK)
- 90° rotation on longitudinal axe
- Free rate (4 boxes x 8 cycles)
- 15 kg (men) / 8 kg (women) = real work

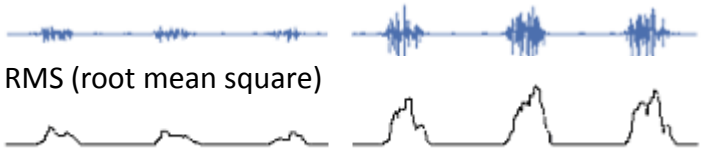


Load carrying during walking (WALK)
- Toolbox carrying
- 4 x 30 m walking (free chosen speed)
- 15 kg (men) / 8 kg (women) = real work

Measures

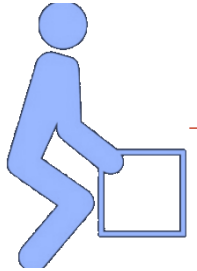
Muscular activity and cardiovascular responses

EMG activity



Heart Rate

HR rest
(5 min)



HR task
(last 30 seconds)

Statistical analyses

Anterior Deltoid (shoulder flexor muscle)

Triceps Brachial (shoulder extensor muscle)

Tibialis anterior (ankle - balance)

Erector spinae (low back - posture)

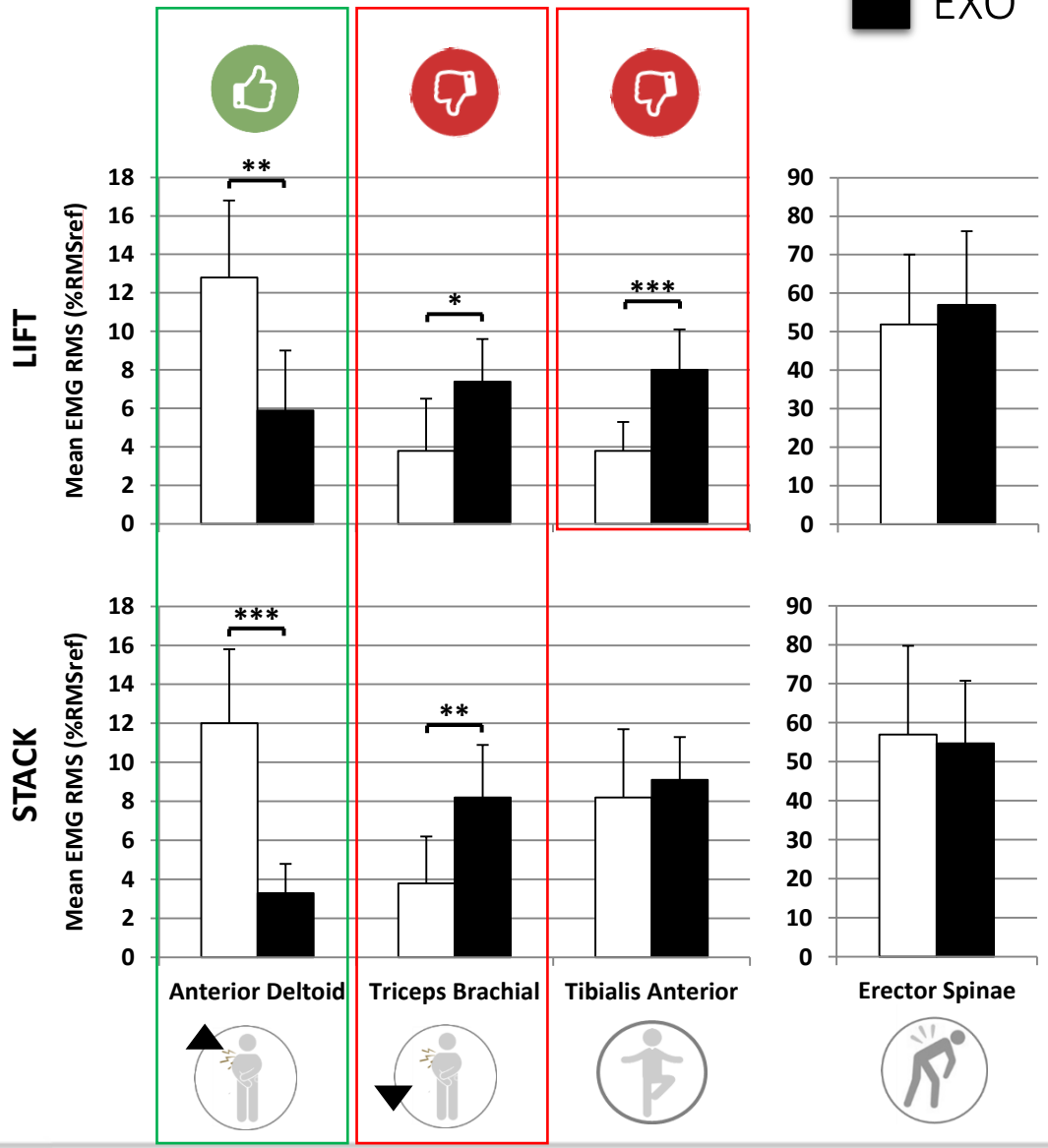
Cardiac cost (HR task - HR rest)

Mixed Linear Model; Subject = random effect; Condition (FREE, EXO) = fixed effect.
* :p<0.05 ; ** : p<0,01; ***p<0,001

Impacts on physiological workload

Muscles activity

EXO versus FREE during lifting and stacking tasks



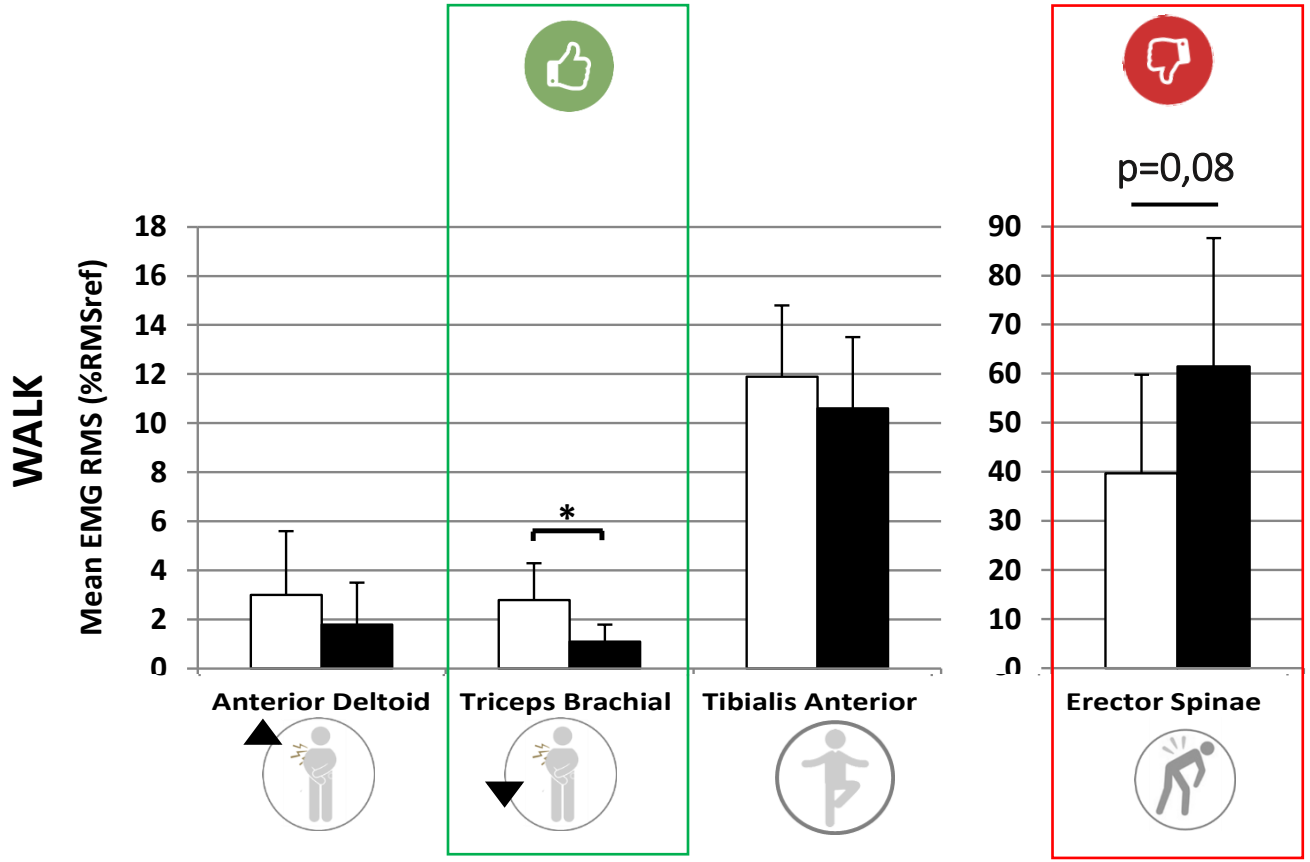
Shoulder flexor muscle
(assisted muscle)

Shoulder extensor muscle
(antagonist muscle)

Ankle muscle
(postural balance)

Muscles activity

EXO versus FREE, during walking task

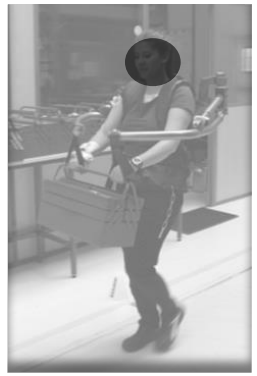


Elbow flexor muscles ?
(decrease of joint torque (elbow))

Lumbar muscles?
(trend) – “lever-arm” effect

Cardiovascular responses

EXO versus FREE



	LIFT		WALK		STACK	
	FREE	**EXO**	**FREE**	**EXO**	**FREE**	**EXO**
Duration (s)	-	-	14.0 ± 1.2	14.7 ± 1.1	36.9 ± 6.7	47.6 ± 7.1 **
Cardiac cost (bpm)	52.1 ± 5.4	59.3 ± 8.2	49.3 ± 9.7	46.0 ± 4.5	66.6 ± 5.2	67.0 ± 7.4

= 3min

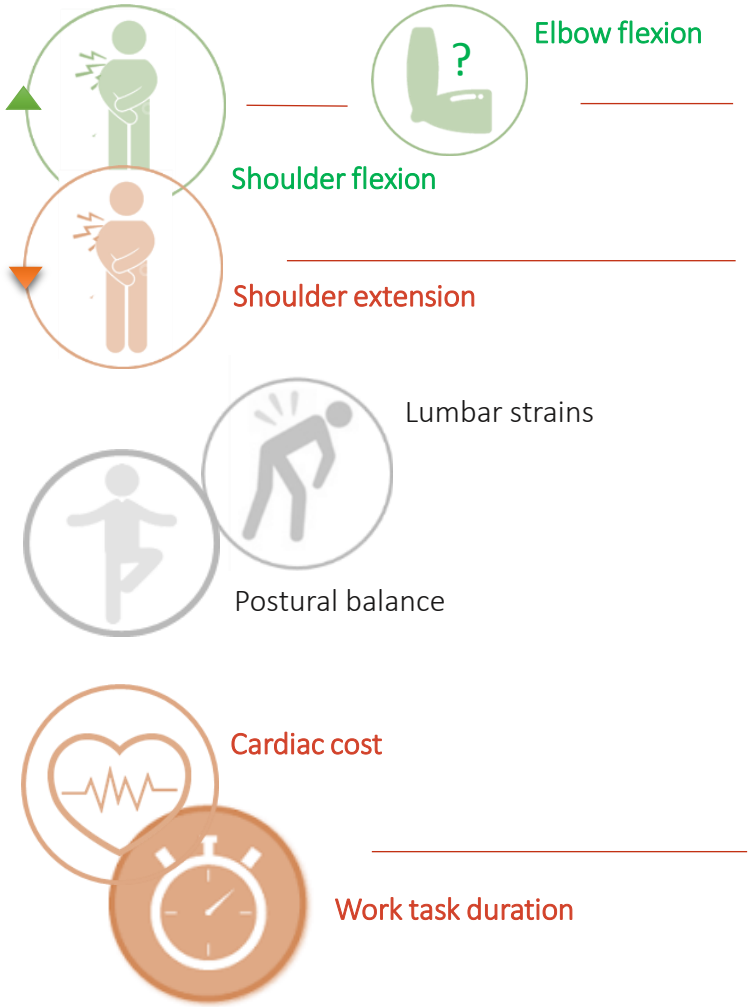
Productivity ~-30%

Strong trend
p=0,058

Identical

Synthesis

Physiological workload : EXO versus FREE



No specific joint assistance !
Depend on movement kinematic, not on tasks, not on joint

Elastic energy storage !
Mechanical strains on antagonist muscles

Mass, inertia or kinematic changes ?

Additional cardiovascular stress
Mass, Kinematic strains, Postural changes

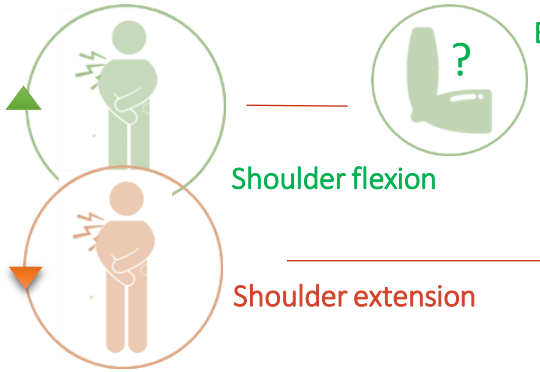
Or …

Lengthening of work task duration

Potential consequences on work organization ?

Consequences on work organization

Various tasks ?



No specific joint assistance !

Depend on movement kinematic, not on tasks, not on joint

Elastic energy storage !

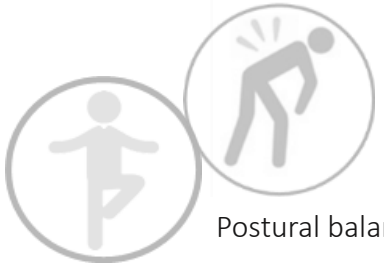
Mechanical strains on antagonist muscle

Reorganization of the daily tasks (individual or team) ?

Tasks with exoskeleton versus those without

Consequences on work organization

Balance and new constrains….



Lumbar strains

Postural balance

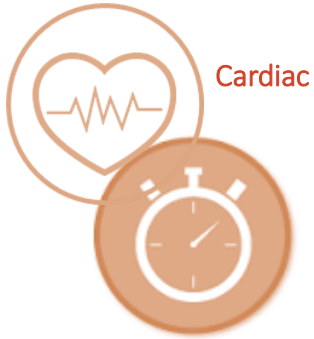
Mass, inertia or kinematic changes ?

Rethinking the work environment ?

Avoid the risks of fall, congested space …

Consequences on work organization

New constrains, and



Additional cardiovascular stress

Mass, Kinematic strains, Postural changes

Or …

Lengthening of work task duration

Rethinking the work organization ?

Allow operators to regulate the work-intensity with exoskeleton

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