Universidad del Rosario

ErgoMotion-Lab

Research in motion and human activity

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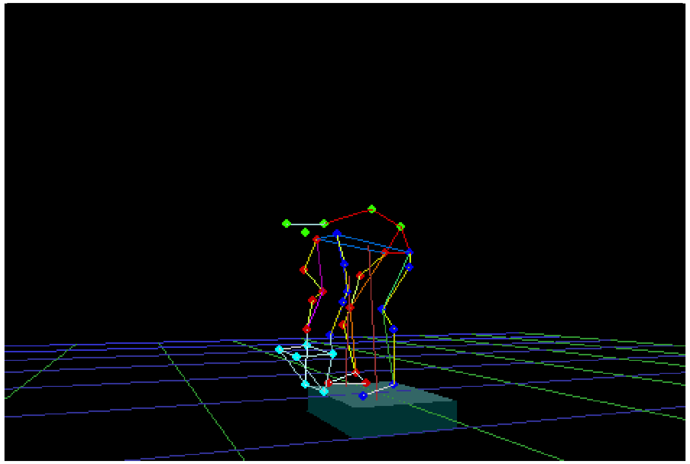
Project:
Training in Motion Analysis – TRAMA- ALFA II



DEVELOPMENT THE NEW PROTOCOL FOR MESURING TRUNK KINEMATICS IN REAL WORK SITUATION

COMPARISON OF TWO METHODS FOR MOVEMENT ANALYSIS IN LOAD LIFTING TASKS

By
Castillo, Juan; Wrooten Win; Orozco, Alejandro

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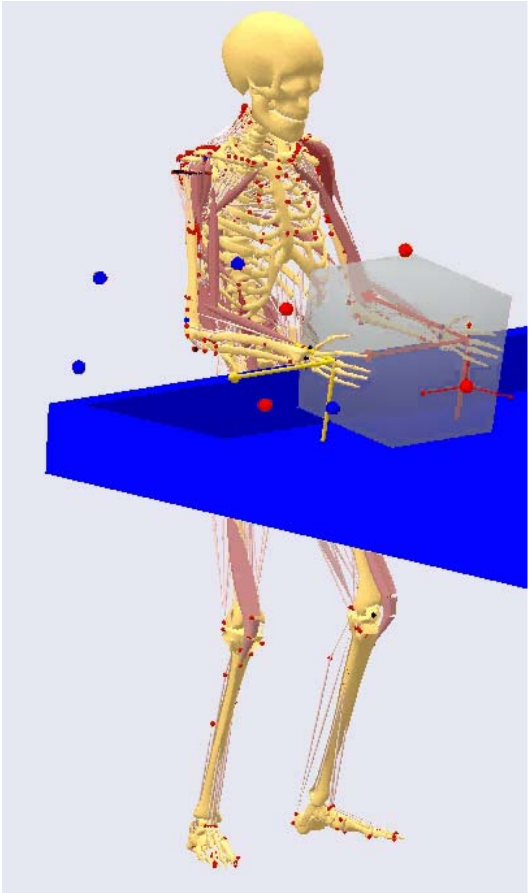


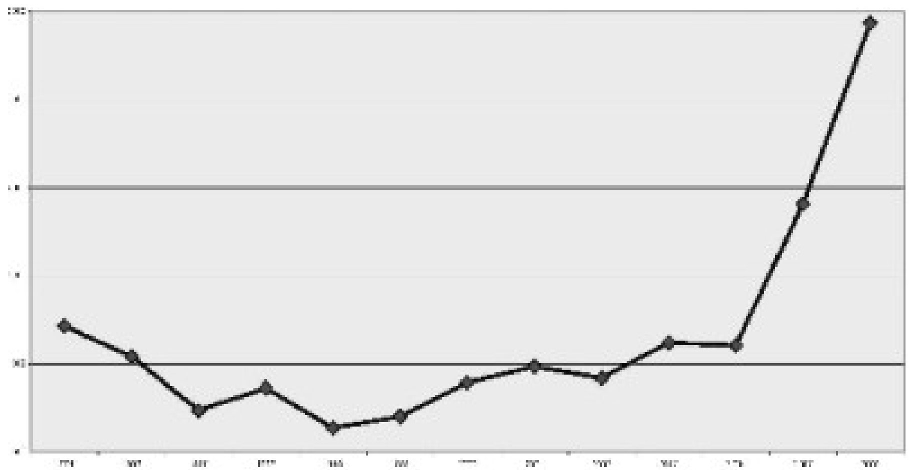
Introduction.

Low back pain (LBP) has a tremendous impact on society both financially and physically [1]. Over **80% of the working population will experience LBP** at some point in time during their lives [1]. LBP is more prevalent for individuals who work in physically demanding jobs where it is the leading cause of disability (up to 47% of the workers are affected) [2]. Recent estimates of the total cost of low back injuries and related pain (both direct and indirect costs) are between **$25 and $95 billion per year** [3]. Thus, there is a tremendous incentive to understand how individuals become injured in the low back while at work as well as during leisure time.

There is increasing evidence that the etiology of occupational low back injuries and pain is multi-factorial in nature, consisting of biomechanical, psychosocial and individual factors. However, recent literature reviews [4] suggest exposure to occupational factors that increase the internal biomechanical loading (e.g. **torso flexion, torso twisting**, etc) account for the majority of the association to occupational low back injuries and pain.

Source: K.G. Davis and M.J. Jorgensen / Biomechanical modeling for understanding of low back injuries: A systematic review. Occupational Ergonomics 5 (2005) 57–76

In Colombia the low back pain remains the second leading cause of occupational disease reported by the health system, its percentage increase from the year 2001 to 2003, from 12% to 22% and declined in 2004 when represented 15% of diagnoses. This perhaps can be explained due to higher other related diagnosis: vertebral disc disorders, which have increased significantly in the years 2003 and 2004.



1994-2006 professional diseases in Colombia

Fuente: Ministerio de la Protección Social

Introduction.

Flexed trunk postures constitute an important risk factor for the development of back pain *(Hoogendoornetal.,2000; L¨ ottersetal.,2003).* Therefore, in ergonomic workplace evaluation, trunk inclination (TI) is used often to characterize back loading *(Talonietal.,2004).* TI is usually measured with observational methods *(Li and Buckle,1999).* Alternatively, TI could be estimated using an inertial sensor (IS) consisting of accelerometers, gyroscopes and magnetometers(Roetenbergetal.,2005), which would be less labor-Intensive and more accurate(LuingeandVeltink,2005).

In ergonomics measures of a workers' "lifted loads", in terms of kgs/day, vertical and horizontal transportations, duration and frequency, number of rests and pauses, and other measures as specified in the NIOSH LOAD LIFTING equation, are studied in order to make recommendations of loads, posture, lifting techniques for the individual worker and to make adaptations to the workplace in order to increase the safety at work for the individual worker.

Perhaps, the use of a combined approach is necessary, in which the ergonomic measures are complemented with movement analyses for better understanding the kinematics and the biomechanical force plays (e.g. joint forces) in the lower back.

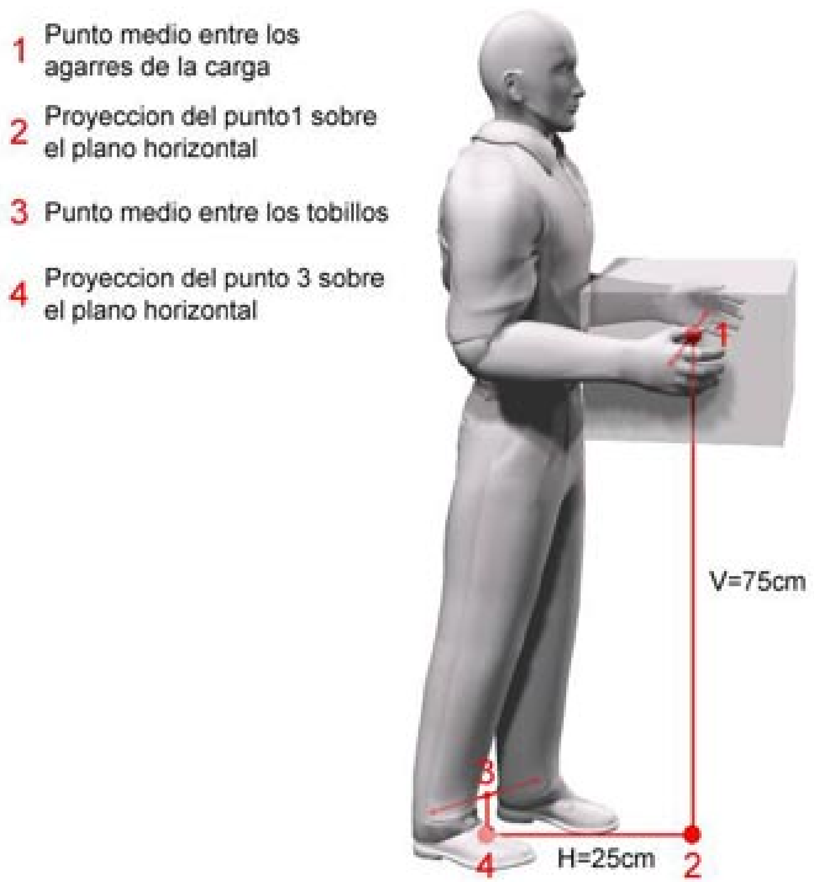
Measuring the angular displacement, velocity and accelerations seems to be key variables for this understanding

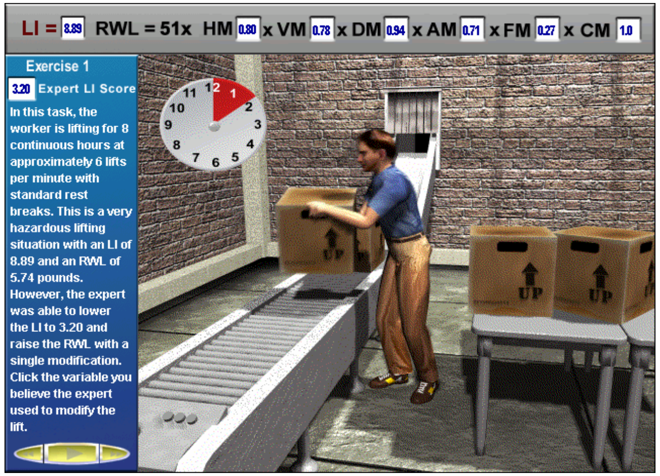
Introduction.

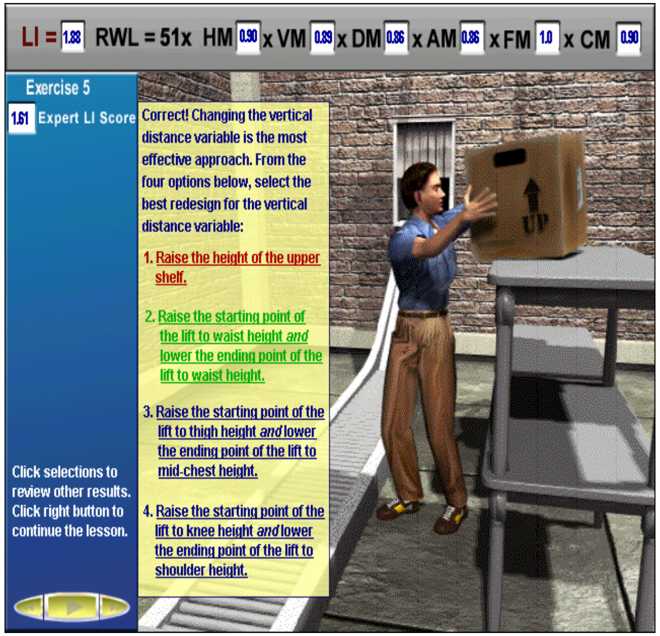
animazoo

the future of motion capture

Introduction.







Introduction.

Lifting and material handling have been associated with the onset of low back pain in several epidemiological studies *(Andersson, 1991, 1999; NIOSH, 1997; Bergquist-Ullman and Larson, 1977; Frymoyer et al., 1983).* In particular, lifting which requires **severe trunk flexion** has been shown to increase the likelihood of low-back disorders (LBDs) *(Marras et al., 1993; Punnett et al., 1991).*

Introduction.

In the **ERGONOMIC FIELD**, the load lifting has been related to additional aspects

1. the relation between **INTERNAL AND EXTERNAL LOADS** at lumbar spine level,
2. the influence of fatigue processes in upper limbs (Chen, 2003)
3. the effects of the **LOAD MASS DISTRIBUTION** (Dennis and Barrett, 2003) to assess the different constraints and lifting techniques observed in the industry with the purpose of counteract the physical stress conditions.

THE VARIABLES taken into account are:

a. **TRUNK DISPLACEMENT** (Van Dieën and De Looze, 1999; Givens et al, 2002; Dennis and Barrett, 2003; Hansen et al, 2007; Anderson et al, 2007; Arjmand et al, 2006; Bazrgaria et al, 2008;)

b. **TRUNK ANGULAR VELOCITY AND ACCELERATION** (Khalaf et al, 1999; Givens et al, 2002; Bazrgaria et al, 2008), range of motion (Andreoni et al, 2005; Arjmand et al, 2006),

c. **MOMENTS AND COMPRESSION FORCES** (Hsiang, S and Mcgorry, 1997; Gallagher et al, 2001; Chen, 2003; Dennis and Barrett, 2003; Bazrgaria et al, 2007; Gallagher et al, 2009).

d. All these variables are extended to study spinal load and biomechanical stress during lifting tasks.

Research question.

¿The angular displacement, velocity and acceleration of the trunk measured with the inclinometer, accelerometer and gyroscope under laboratory conditions and in the real task, are comparable with measurements performed by the optoelectronic system?

The specific research questions for this project are:

1. Are the angular displacement, velocity and acceleration of the trunk measured with the CAPTIVE L3000 system under laboratory conditions comparable with measurements performed by BTS system?
2. Are the angular displacement, velocity and acceleration of the trunk measured with the portable systems under laboratory conditions reliable in terms of inter- and intra-trial variability?
3. Are the angular displacement, velocity and acceleration of the trunk measured with the CAPTIVE L3000 system during worksite measurements comparable with measurements of these variables under laboratory conditions?

Research question.




The accelerometers in the motion analysis.

An alternative approach to conventional movement analysis techniques, such as optoelectronic and force plate motion analysis, involves the use of accelerometers and gyroscopes attached to the body for the purpose of examining segmental accelerations.

THE BENEFITS of using this devices to assess movement include: the low cost compared to more commonly used movement laboratory equipment; testing is not restricted to a laboratory environment; the accelerometers make direct measurement of 3D accelerations eliminates errors associated with differentiating displacement and velocity data.

Method of fixation	Accelerometer location	Study
Skin adhesive	Upper trunk	Yack and Berger
Surgical tape	Upper trunk	Manson et al.
Firm fitting belt	Lower trunk	Akay et al., Auvinet et al. Menz et al., Meijer et al. Moe-Nilssen., Robinson et al. Schutz et al., Sekine et al. Smidt et al.
Elastic bandages	Lower trunk	Zijlstra
Velcro straps	Lower trunk	Gage. Mansfield and Lyons

From: J.J. Kavanagh, H.B. Menz ., Accelerometry: A technique for quantifying movement patterns during walking. Gait & Posture 28 (2008) 1–15

Aims.

Aim.

The aim the study was to validate measures of angular displacement, velocity and acceleration of the trunk during load-lifting tasks measured with portable ergonomic measurement systems compared with optoelectronic laboratory systems.

Secondary aim

To test whether worksite measures of angular displacement, velocity and acceleration of the trunk during load-lifting tasks measured with portable ergonomic measurement systems are comparable with experimental laboratory conditions.

Methods.

The study was carried out using two different portable measurement systems in two countries (Sweden and Colombia):

a. inclinometer measurements in Sweden
b. CAPTIVE 4000 system in Colombia, (accelerometer, gyroscope and torsiometer)

SET-UP

the use of one standardized experimental set-up at two different movement analysis laboratories in which similar optoelectronic systems were used (the BTS system).

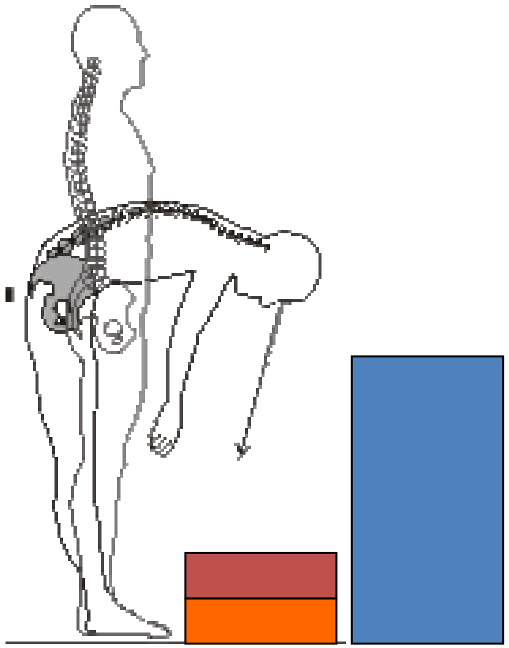
THE VARIABLES OF INTEREST ARE

1. the angular displacement of the trunk during a load-lifting task.
2. The velocity of the trunk during a load-lifting task.
3. The acceleration of the trunk during a load-lifting task.

MEASUREMENT SYSTEMS

- Inclinometer (Karolinska) rate of recording 25 Hz using telemetry
- CAPTIVE 4000 system (portable system): rate of recording 25 Hz using telemetry
- BTS system optoelectronic lab: rate of recording 75 Hz.

Parameters to be measured



DESCRIPTION OF THE LOAD-LIFTING TASK UNDER LABORATORY CONDITIONS

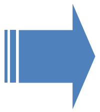
Activity: The subject lifted up a box with 17.5 kg from the floor and placed it on a surface of 75 cms high.

After that, the subject continued immediately to lift another box from the floor: that means that the lifting task was done twice in the same trial.

The way of load lifting is "stood", i.e. a free style lift with a normal speed (subject's speed) during the activity. A free style stood lift is considered as the style that the subject naturally choose , that is, the knees in semi flexion (5 to 10 degree), hip and low back flexion as much as the subject reach the box on the ground.

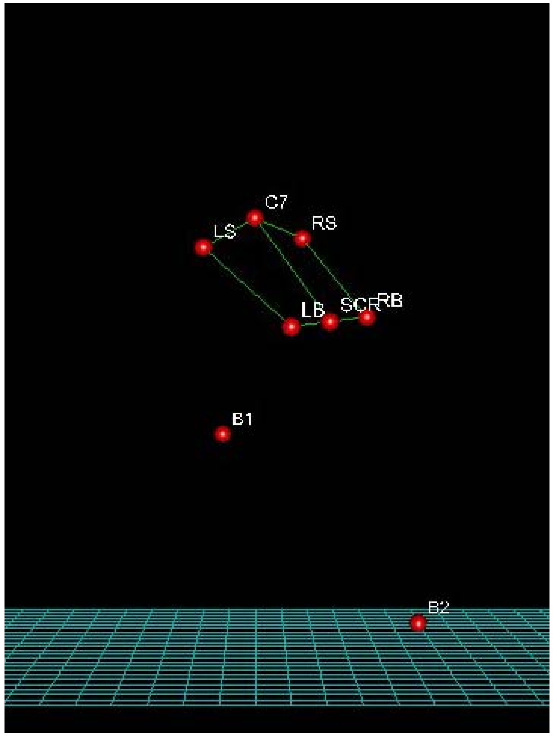
Trunk angles definition:

1. **Trunk inclination respect to the vertical direction in sagittal plane**
2. **Trunk lateral bending in the frontal plane**
3. **Trunk torsion in the horizontal plane**



- angles and angular displacement
- angular velocity
- angular acceleration

Parameters to be measured

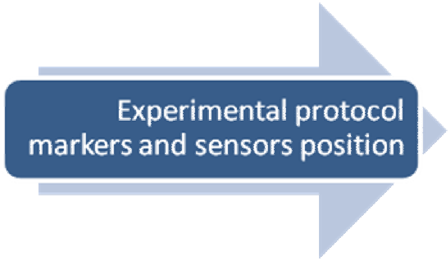


For the purpose of the methodology each lift was divided in two phases:

1)Going downwards (grasp the box)
2)Going upwards (lift the box and place it on the surface)

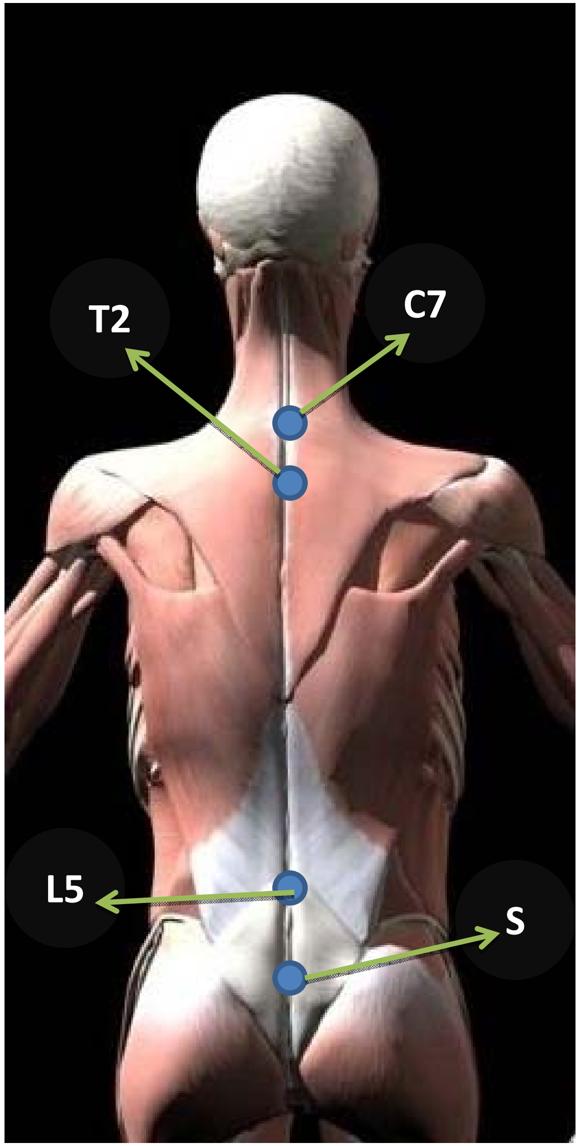
That means the whole trial consist of four phases (two going down and two going up). Each trial was repeated two times in order to be able to study the inter- and intra-trial variability.

Motion analysis protocol

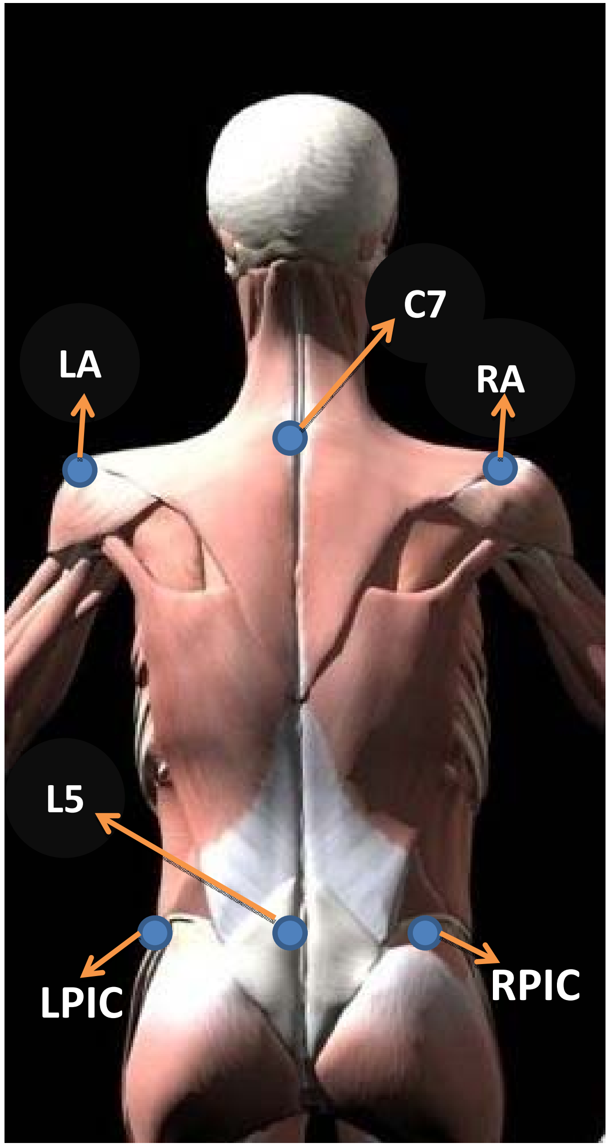


Markers utilised

C7: cervical vertebra
T2: thoracic vertebra
L5: lumbar vertebra
S: sacrum
LA: left acromion
RA: right acromion
LPIC: left posterior iliac crest
RPIC: right posterior iliac crest

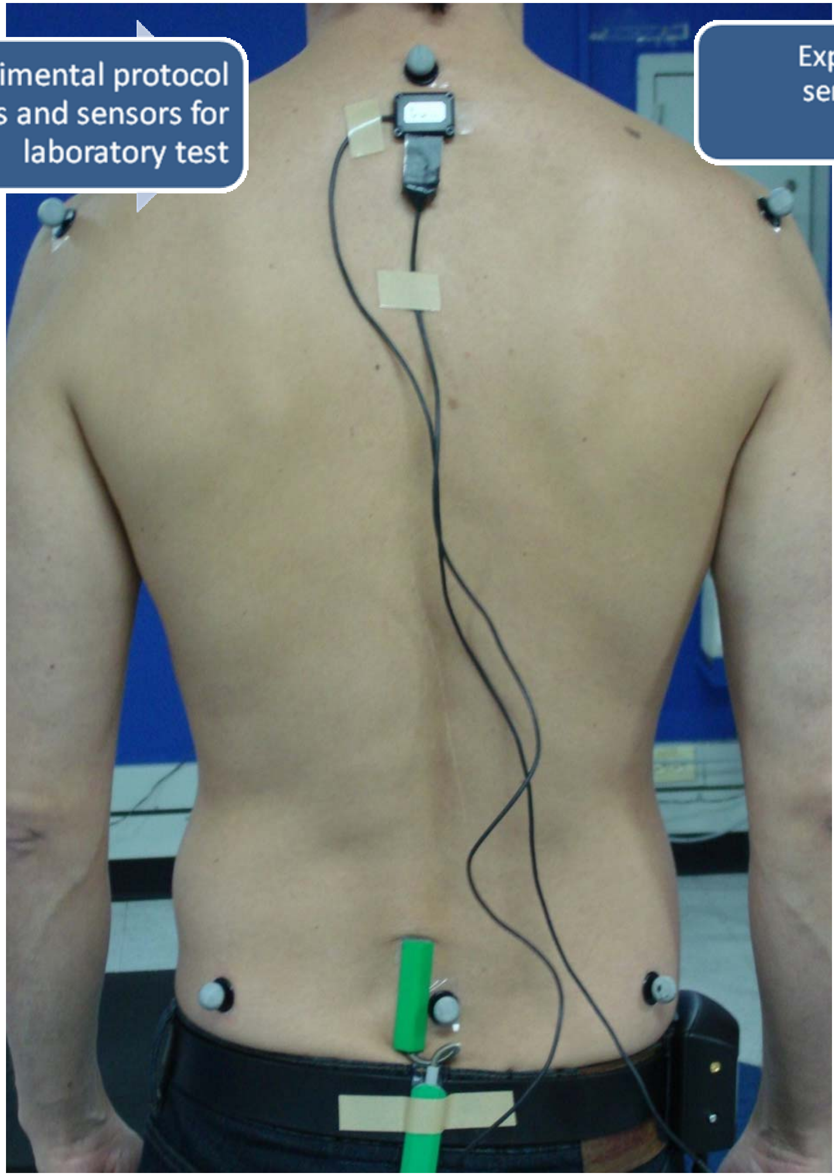


Sensors for Captiv/l4000

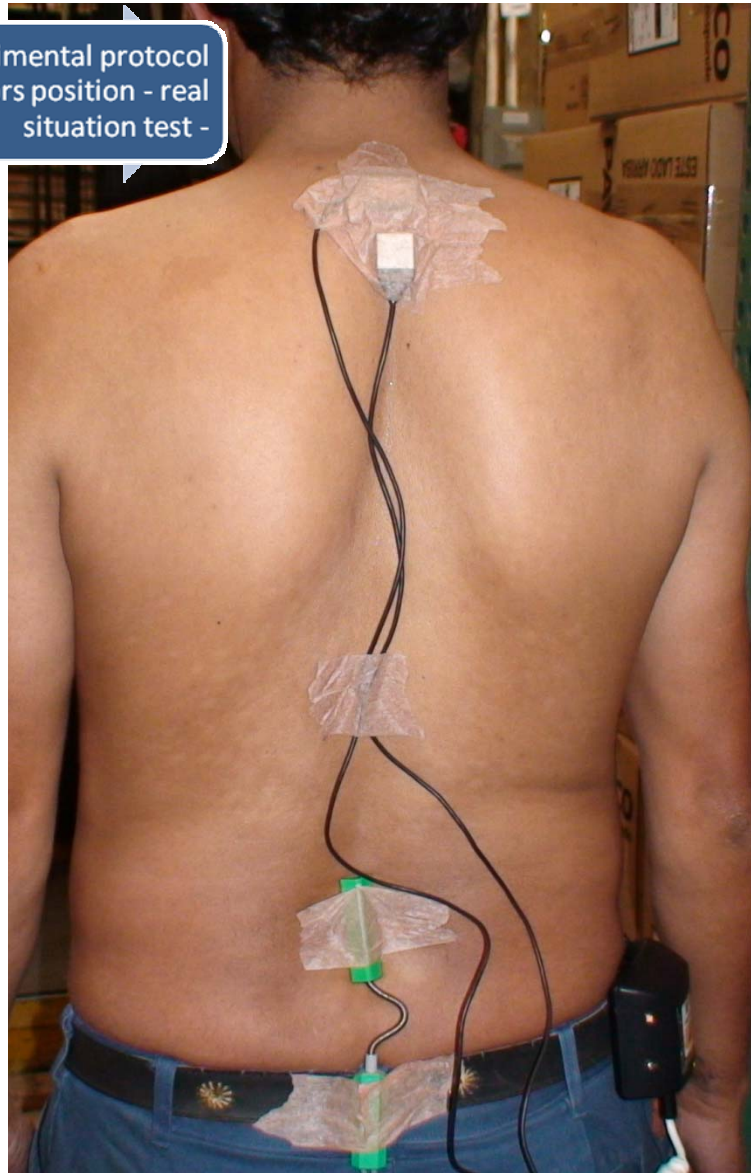


Markers for BTs/elite 75Hz

Motion analysis protocol

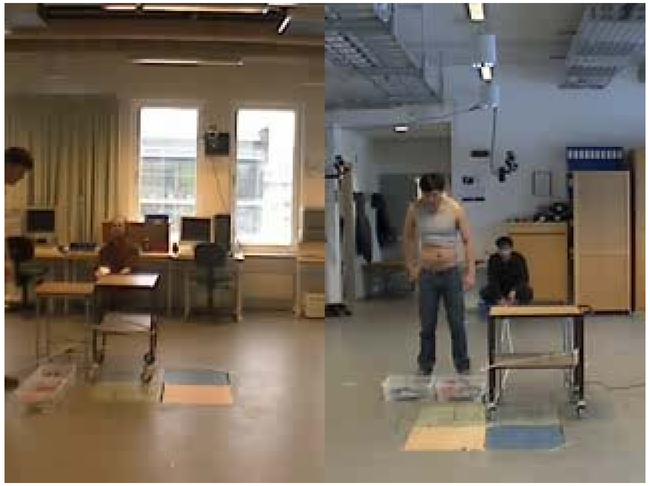


Sensors for Captiv/L3000 and
Markers for BTs/



Sensors position for Captiv/3000

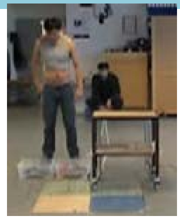
Test in laboratory – Sweden-

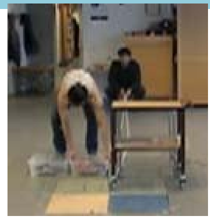


Test in laboratory – Colombia-

Test in specific real work situation

Preliminary results





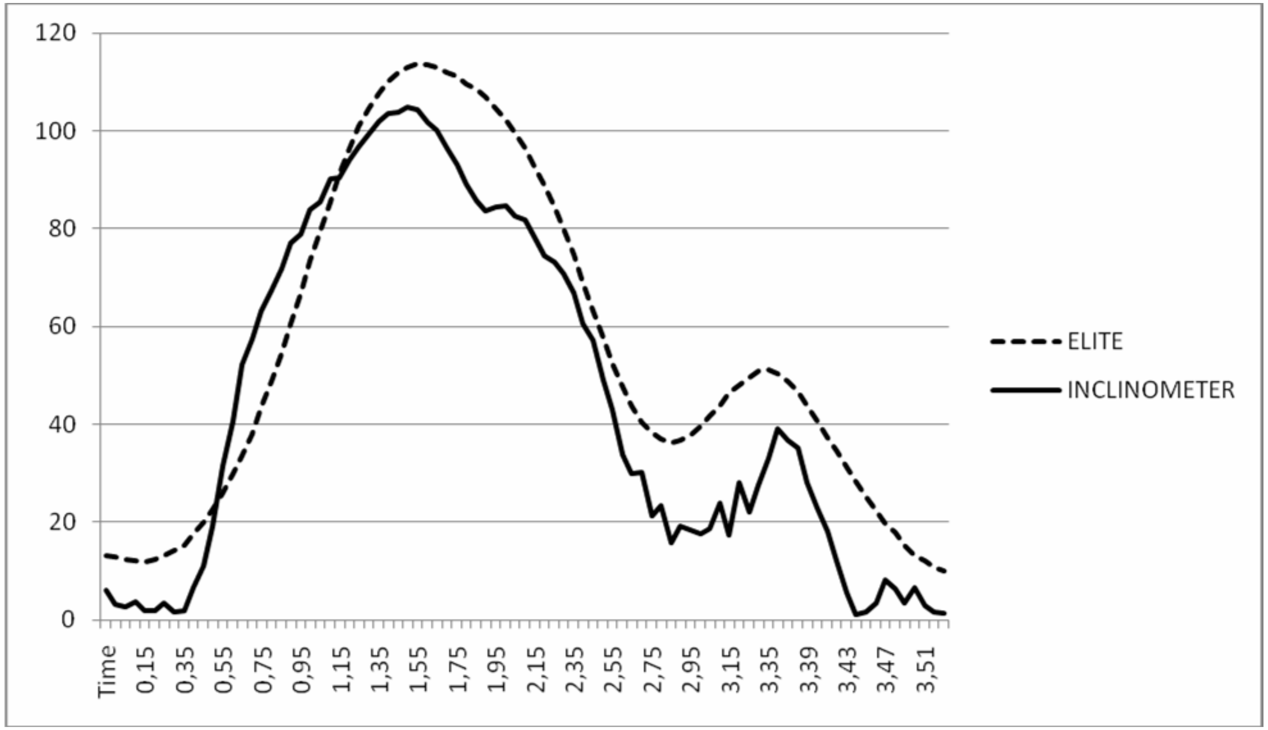
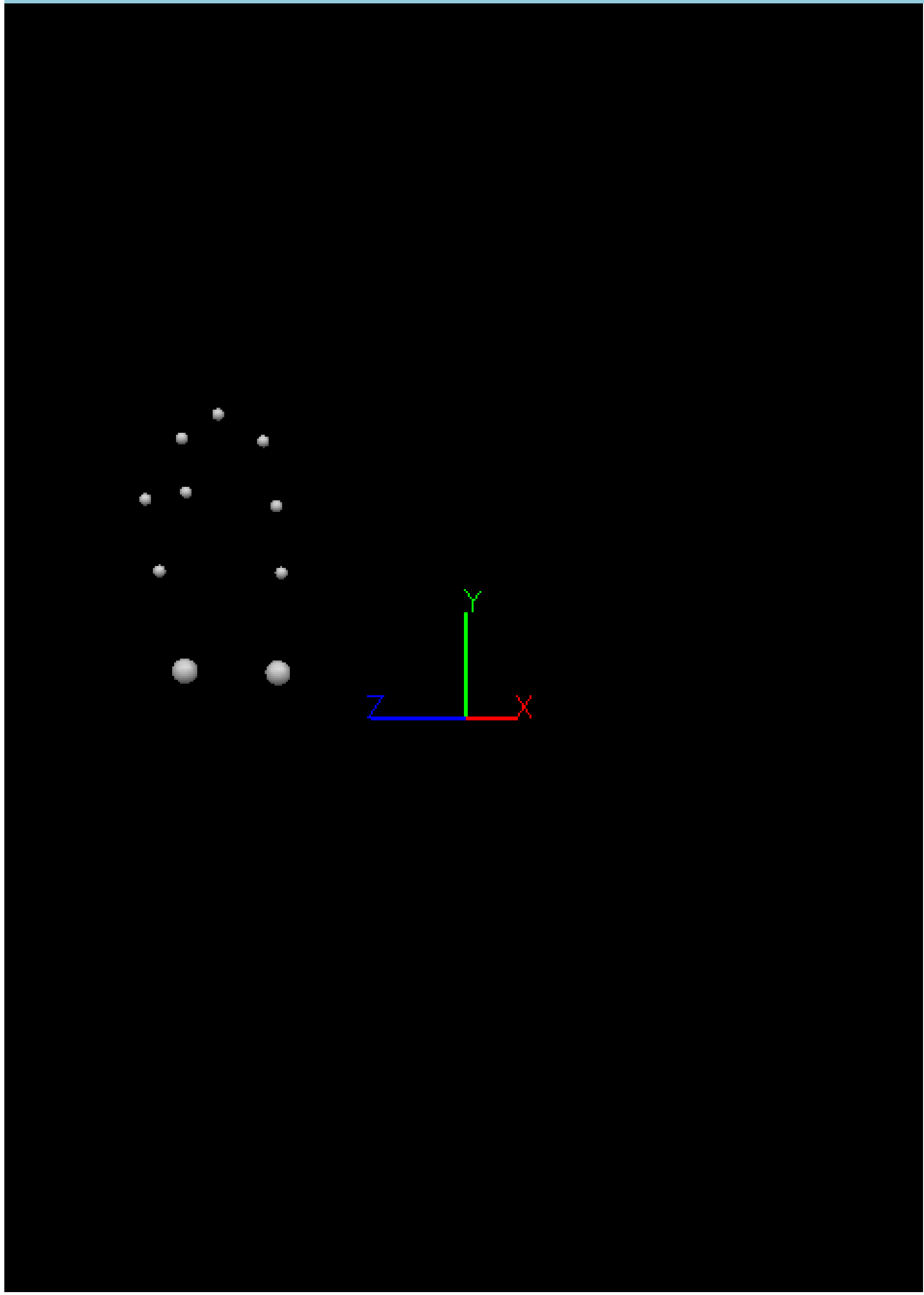
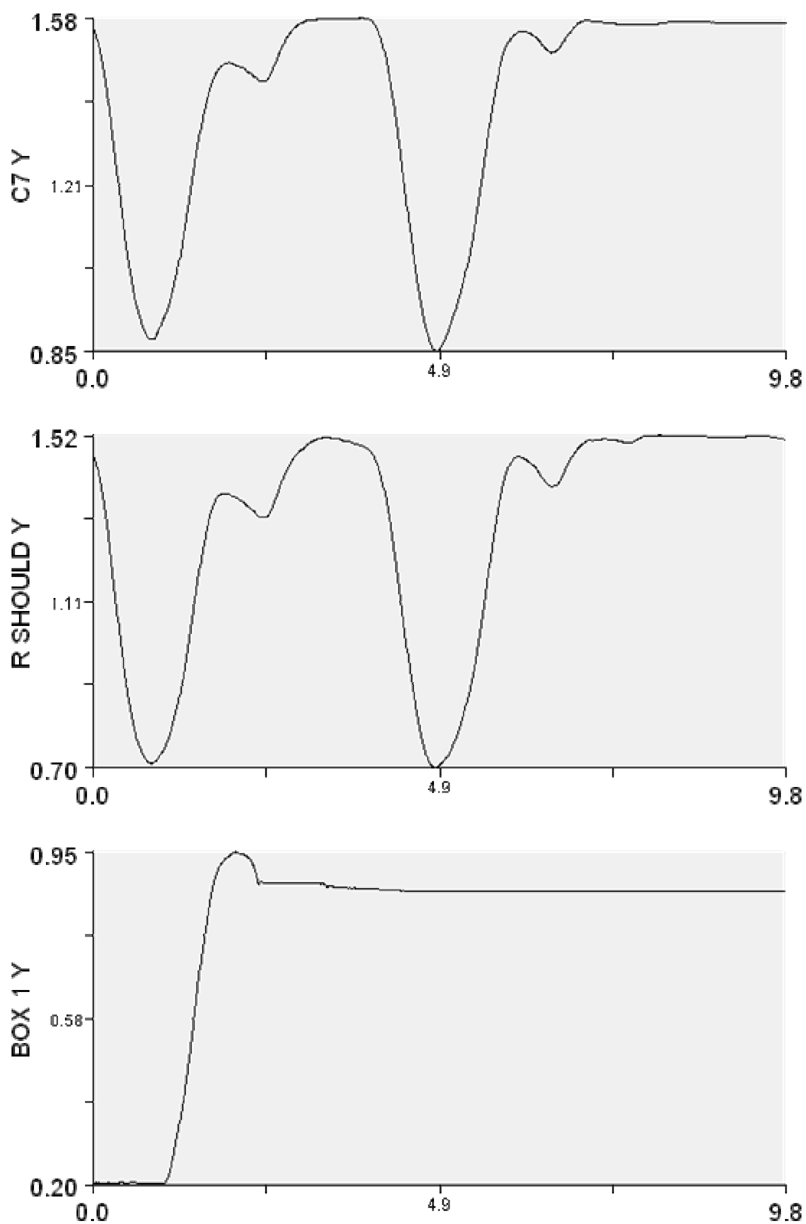


Figure 1: Typical displacement curve (degrees) vs time (seconds) for the Elite system at 100Hz at the movement science laboratory in Sweden and simultaneous inclinometer recordings C7(Swedish measurements). Note that in order to enable a comparison, only 2 measurements each ms were taken from the Elite system (20Hz).



Y
Z
X



1.58
C7 Y
1.21
0.85
0.0
4.9
9.8
1.52
R SHOULD Y
1.11
0.70
0.0
4.9
9.8
0.95
BOX 1 Y
0.58
0.20
0.0
4.9
9.8

Preliminary results

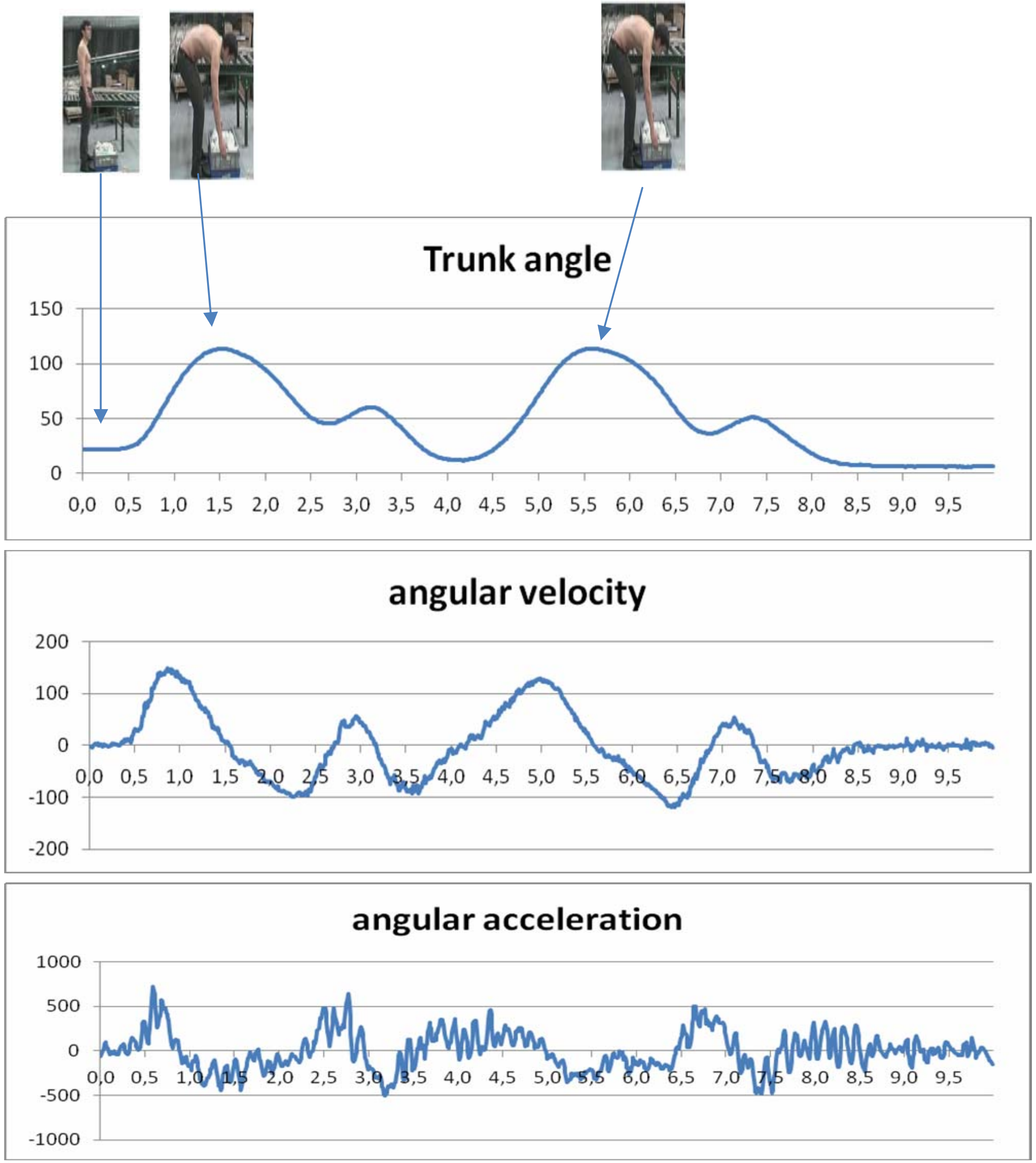


Figure 2. The three parameters of importance:

1. ***angular displacement (trunk flexion angle),***
2. ***angular velocity and***
3. ***angular acceleration of the trunk, measured with the Elite system at 100Hz at the movement science laboratory in Sweden.***

Note that when the displacement curve reaches its peak, the velocity curve is crossing the zero line and when the velocity curve reaches its peak, the acceleration curve is crossing the zero line.

Preliminary results

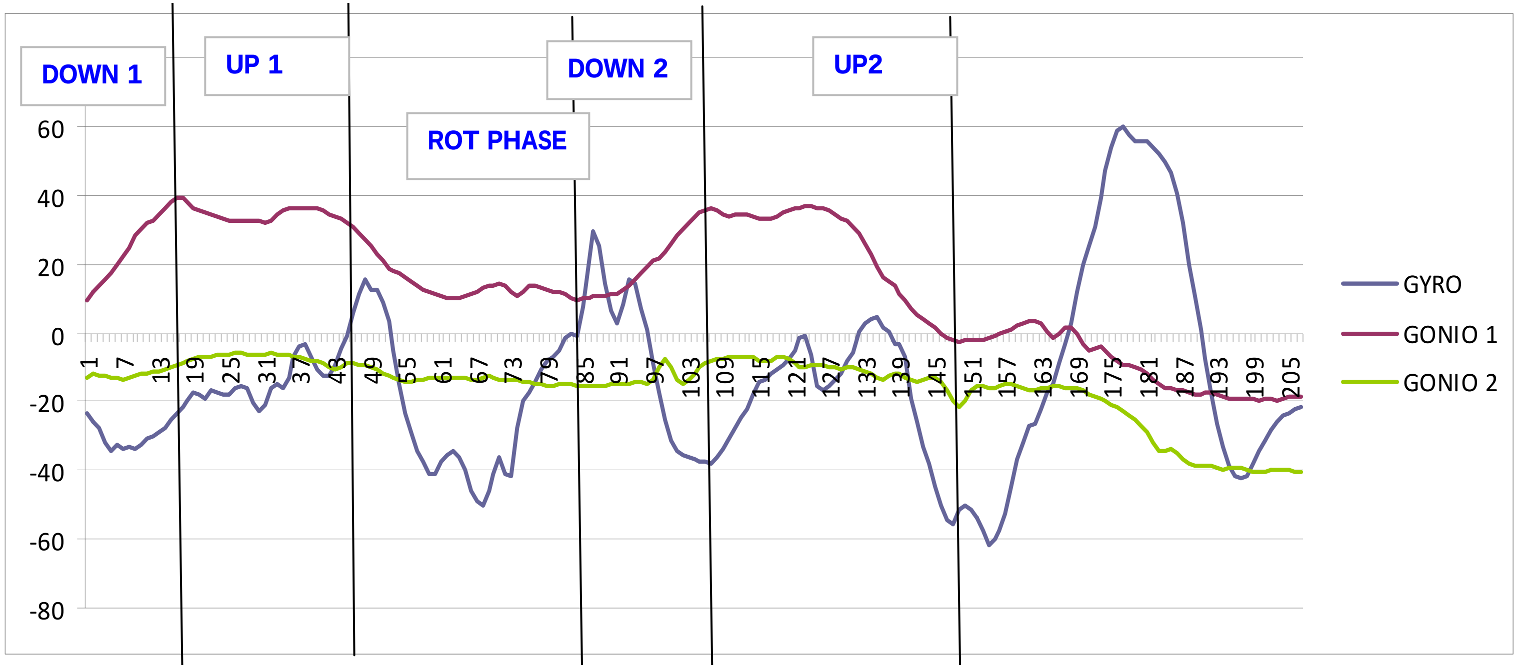
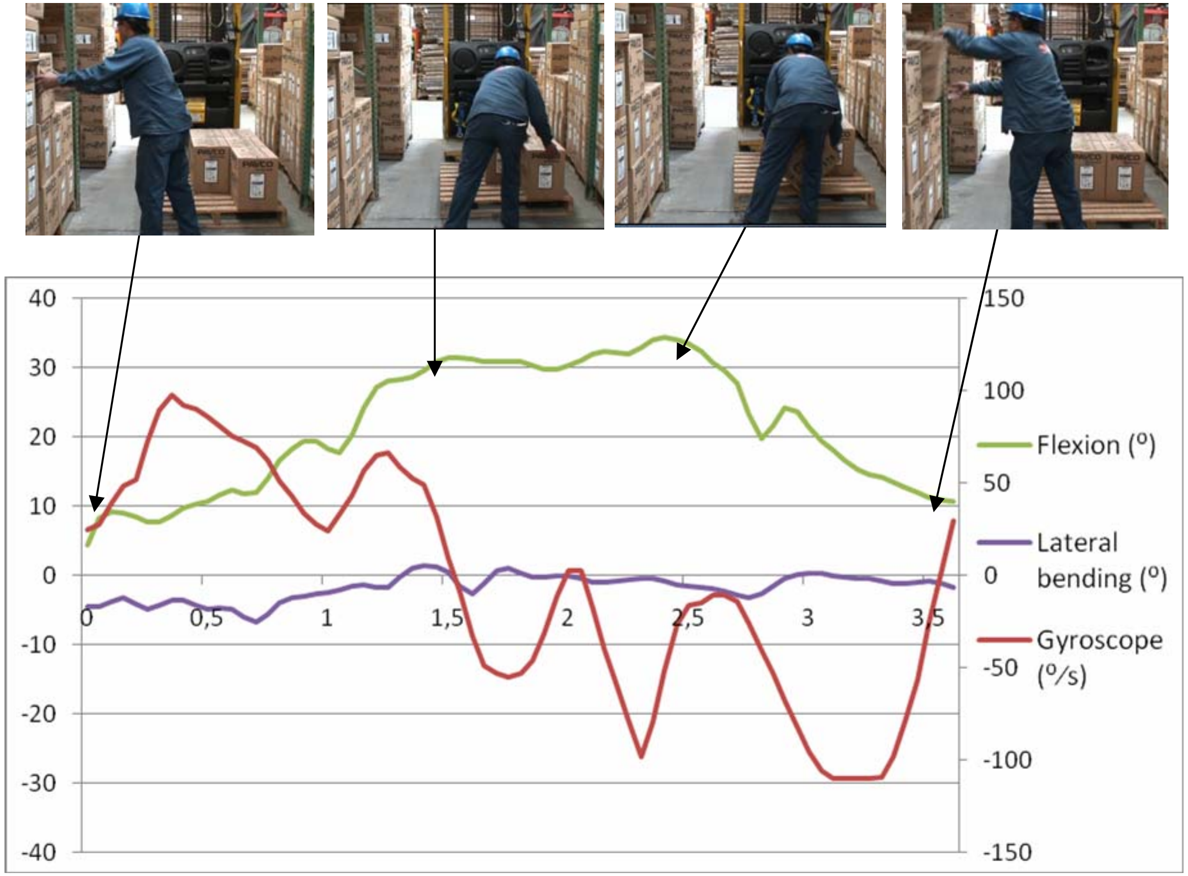


Figure 3. The three parameters of importance:
In red the trunk flexion angle,
In green the trunk lateral deviation
In blue the rotation of the trunk,
measured with the CAPTIV system at 25Hz at the movement science laboratory in Colombia

Preliminary results



Example of one lift situation (up to down to up) for the worker at the company, lifting 17,5 kg during approximately 3,5 seconds. The curve shows simultaneous recording of the flexion angle (º), the lateral bending (º) and the gyroscope (º/s) over time. Note that while flexed, the worker lifts first the box to one edge and changes his grasp to the bottom of the box before starting the up-phase. This could perhaps explain the several changes of direction in the gyroscope curve (positive numbers indicate a trunk rotation to the right and negative numbers means rotations to the left). Note also that the gyroscope is not able to record rotations faster than ±112º, thus cutting the lowest peak.

Conclusion

Ergonomists mostly observe workers by taking pictures/videos to get some quantitative data on angles or velocity, but, although using standardized protocols, the data obtained is often too crude to get a deeper understanding of injury mechanisms.

For that reason, most of the biomechanical studies done on angular displacements, velocity and accelerations are performed under laboratory conditions

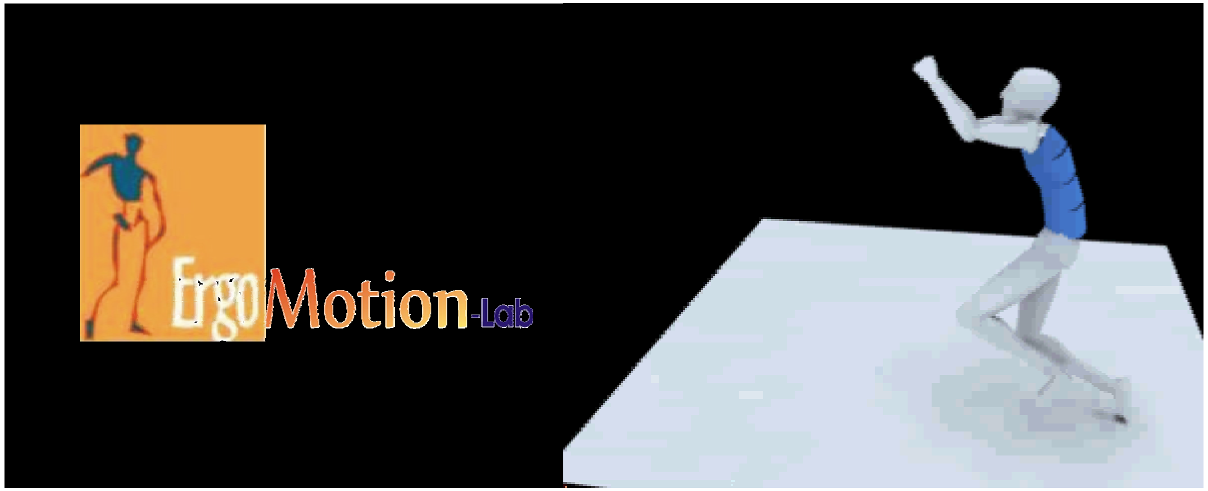
However, connecting workers with EMG, optoelectronic markers, and forcing them to stand within the borders of force platforms seems to make the experimental set-up very rigid and different from actual situations in the workplace.

If this is the case, the usefulness of laboratory experiments of load lifting tasks can be questioned, leaving the ergonomists unsure in their general recommendations on load-lifting.

Conclusion

1. The variation in the flexion and rotation angle of trunk are influenced by the strategies of planning and control of acceleration, accuracy and speed of movement execution.
2. The stability of the load influence lateral deflections and rotation of the trunk
3. The acceleration and velocity change rapidly at the beginning and end of movement performed
4. Muscle activation prior to the execution of the movement, indicates the development of stabilization strategies along the path described.
5. The development of a protocol for recording and processing of data includes the integration of the variables described above
6. The trunk stabilization strategy is associated with learning and motor development of gesture

Ergo-motion laboratory



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Escuela de Medicina y Ciencias de la Salud

TRAMA TRAining in Motion Analysis

Thanks and Welcome to Bogotá

03/2010
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