MOVEMENT ANALYSES IN LOAD LIFTING TASKS

Comparison of two methods for capturing and analyses of trunk kinematics

GROOTEN WIM1; CASTILLO, JUAN2; OROZCO ALEJANDRO3
1-PHD, RPT. KAROLINSKA INSTITUTET, DEP OF NEUROSCIENCE.
2-PHD. MG. ROSARIO UNIVERSITY, ERGOMOTION LAB
3PT ROSARIO UNIVERSITY, ERGOMOTION LAB,

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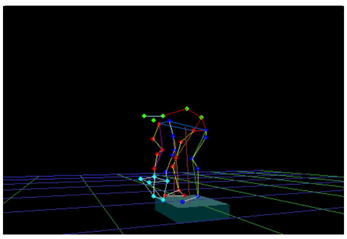

COMPARISON OF TWO METHODS FOR MOVEMENT ANALYSIS IN LOAD LIFTING TASKS
By
Grooten Win; Castillo, Juan; Orozco, Alejandro

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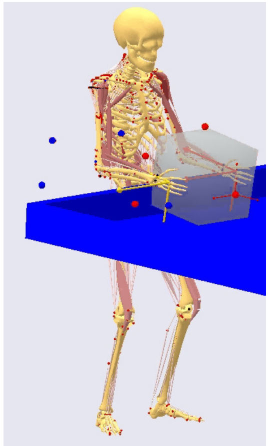


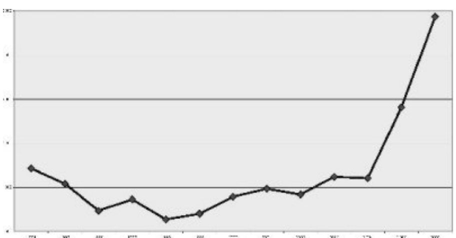
Introduction.

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.

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:

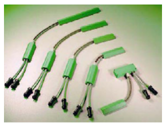
a. **TRUNK DISPLACEMENT** (Van Dieën and De Looze, 1999; Givens et al, 2002; Dennis and Barrett, 2003; Hansen et al, 2007; Anderson et al, 2007; Arjmand et al, 2006; Bazrgaria et al, 2008;)

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 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

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?

Aims.

Aim.
The aim of the study was to compare portable ergonomic measurement systems against optoelectronic laboratory systems regarding measures of peak trunk flexion and peak trunk rotation angles, peak velocity as well as peak acceleration of trunk movements during load-lifting tasks. An additional aim was to test whether work site measures of trunk motion during load-lifting tasks measured by portable ergonomic measurement systems are comparable with load-lifting tasks in laboratory conditions.

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):

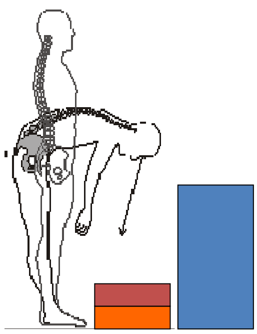
a. inclinometer measurements in Sweden
b. CAPTIVE 4000 system in Colombia, (accelerometer, gyroscope and torsiometer)

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.

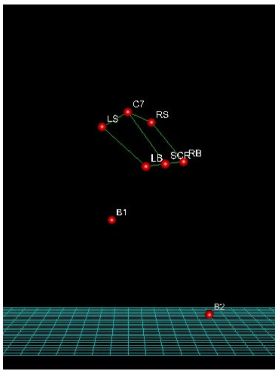
Trunk angles definition:

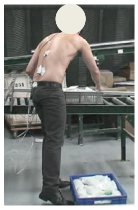
1. **Trunk inclination respect to the vertical direction in sagittal plane**
2. **Trunk lateral bending in the frontal plane**
3. **Trunk torsion in the horizontal plane**

→

- 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)

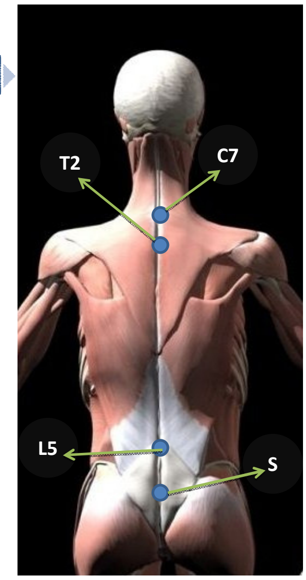
That means the whole trial consist of four phases (two going down and two going up). Each trial was repeated two times in order to be able to study the inter- and intra-trial variability.

Motion analysis protocol

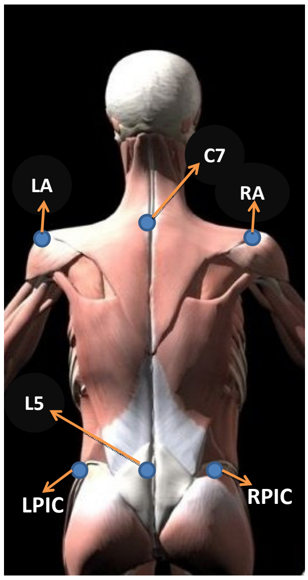
Experimental protocol markers and sensors position

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

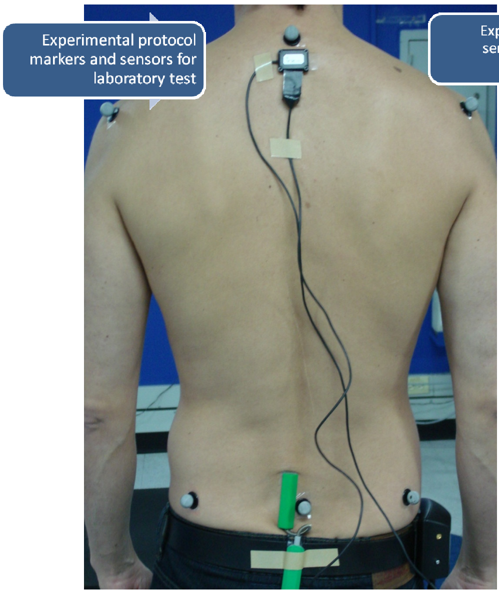


Sensors for Captiv/I4000

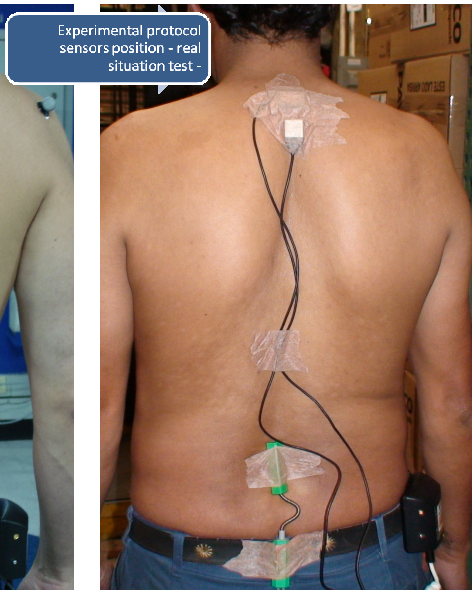


Markers for BTs/elite 75Hz

Motion analysis protocol

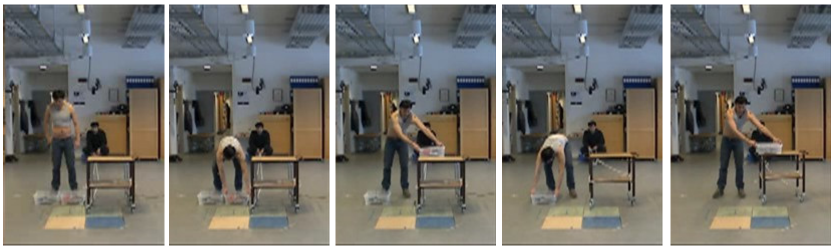


Sensors for Captiv/L3000 and
Markers for BTs/



Sensors position for Captiv/3000

Test in laboratory – Sweden-



Test in laboratory – Sweden-

Test in laboratory – Sweden-

Test in laboratory – Colombia-

Test in specific real work situation

Test in specific real work situation

DATA ANALYSES

RESULTS

FINAL REMARKS

RELIABILITY

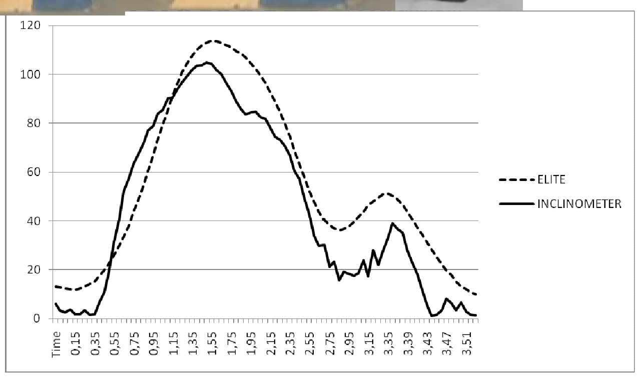
Intra reliability [within one measurement method; i.e. between trials]

Inter reliability [between measurement methods]

RELATIVE RELIABILITY
ICC Intraclass correlation coefficient: excellent >0.9, poor <0.4

ABSOLUTE RELIABILITY
ANOVA; SEM standard error of the mean; CV% coefficient of variation

Typical results from one trial



example
comparison between trials and between 2 systems

	Trunk flexion angle Box 1	Trunk flexion angle Box 2
INC trial 4	112,3	100,2
BTS trial 4	108,5	111,5
INC trial 8	96,1	101,7
BTS trial 8	99,2	103,9
INC trial 12	102,4	104,2
BTS trial 12	105,4	111,4
MEAN INC	**103,6**	**102,0**
MEAN BTS	**104,4**	**111,5**

ANGLES	INTRA-TRIAL RELIABILITY		CONSISTENCY BETWEEN INC AND BTS
	INCLINOMETER	BTS	
SEM	5,49	3,34	4,26
CV%	5,34	3,14	4,06
ANOVA	0,798	0,027	0,126
ICC	0,587	0,972	0,668

RESEARCH QUESTION 1a.

Are inclinometer measures (INC) of **peak trunk flexion angle** under laboratory conditions reliable and comparable with measurements performed by the BTS system?

ANSWER:

YES , with better reliability coefficients for the BTS

RESEARCH QUESTION 1b

Are inclinometer measures (INC) of **peak trunk angular velocity** under laboratory conditions comparable with measurements performed by the BTS system?

ANSWER:

YES Reliable for BTS, lower for INC

NO for comparability

VELOCITY	INTRA-TRIAL RELIABILITY		CONSISTENCY BETWEEN INC AND BTS
	INCLINOMETER	BTS	
SEM	57,48	15,70	94,80
CV%	18,77	8,55	38,70
ANOVA	0,368	0,026	0,040
ICC	0,537	0,996	0,198

RESEARCH QUESTION 1c

Are inclinometer measures (INC) of **peak trunk angular acceleration** under laboratory conditions comparable with measurements performed by the BTS system?

ANSWER: (same answer)

YES Still reliable for BTS, lower for INC

NO for comparability

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RESEARCH QUESTION 2a.

Are the peak **trunk flexion angles** of the trunk measured with the captive 3000 system under laboratory conditions reliable and comparable with simultaneous measurements performed by BTS system?

ANSWER:

Comparable: NO!

Reliable: YES for BTS

GONIO METER		ANGLE	
METHOD		GONIO	BTE
TEST 1	BOX 1	52,3	100,4
	BOX 2	43,8	94,0
TEST 2	BOX 1	46,9	101,1
	BOX 2	50,6	96,8
TEST 3	BOX 1	47,6	95,6
	BOX 2	49,5	100,5
TEST 4	BOX 1	46,5	98,6
	BOX 2	48,9	91,5
TEST 5	BOX 1	45,7	97,0
	BOX 2	47,9	104,7

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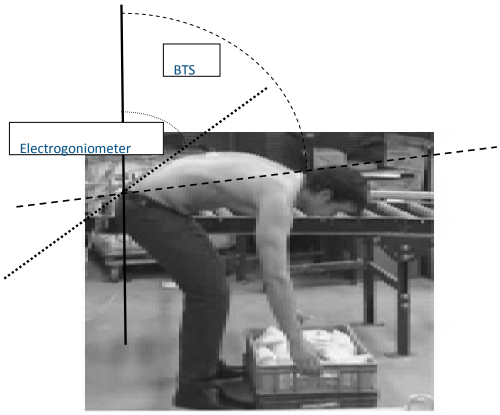

TRUNK FLEXION ANGLE	INTRA-TRIAL RELIABILITY		CONSISTENCY BETWEEN INC AND BTS
	ELECTRO GONIOMETER	BTS	
SEM	7.36	4.39	42.61
CV%	17.14	4.48	62.69
ANOVA	0.000	0.751	0.000
ICC	0.407	0.975	0.117

RESEARCH QUESTION 2b.

Are the peak trunk **angular velocity** and **acceleration** of the trunk measured with the captive 3000 system under laboratory conditions reliable and comparable with simultaneous measurements performed by BTS system?

* ANSWER: VELOCITY

Comparable: NO!

Reliable: YES for BTS (up phase), NO for CAPTIVE 3000

* ANSWER: ACCELERATION

Comparable: NO!

Reliable: MODERATE for CAPTIVE 3000 (Up phase)

RESEARCH QUESTION 2c.

Are the peak **trunk rotation** angles of the trunk measured with the captive 3000 system (GYROSCOPE) under laboratory conditions reliable and comparable with simultaneous measurements performed by BTS system?

ANSWER:

Comparable: NO!

Reliable: YES for BTS in the UP (to the left) phases only.

Moderate for the GYRO

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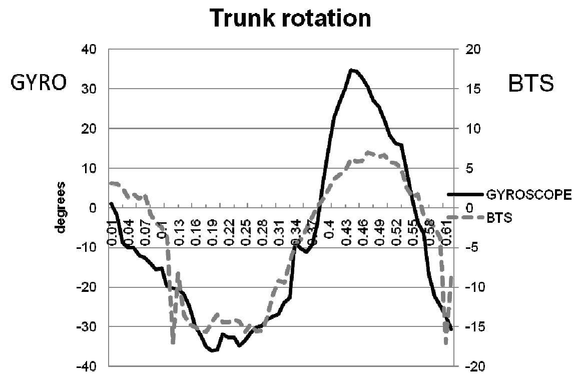

ROTATION UP-PHASE	INTRA-TRIAL RELIABILITY		CONSISTENCY BETWEEN INC AND BTS
	GYRO	**BTS**	
SEM	15,4	2,62	23,1
CV%	-31,8	-14,1	-68,8
ANOVA	0,130	0,022	0,009
ICC	0,402	0,895	0,097

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FINAL RESEARCH QUESTION

Are the peak flexion angles of the trunk measured with the captive 4000 system during worksite measurements comparable with measurements of these variables under laboratory conditions?

	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6	mean
Trial 1	36,1	31,4	34,9	32,1	29,8	37,2	**34**
Trial 2	41,4	48,9	65,9	87,5			**61**
Trial 3	32,7	31,5	36,6	41,9	43,5	38,6	**37**

ANSWER

In field measurements, the electrogoniometer has shown good relative and absolute reliability ICC=0,805; CV%=9,9% for box 1 and 2 but a very low INTERDEVICE reliability (0.116)

FINAL REMARKS

• In laboratory situations, the BTS showed excellent **intra-trial reliability**, while the portable ergonomic measurement instruments showed poor/moderate intra-trail reliability for most of the variables studied.

• The inter-device reliability was good for the Inclinometer and the BTS concerning trunk angles, but not for the derivations (velocity/accelerations)

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FINAL REMARKS (cont.)

The inter-device reliability was LOW for the electrogoniometer and the BTS, but the inter-trial reliability was 0.81 for the first two boxes in workfield measures.

The gyroscope showed moderate inter-trial reliability concerning trunk rotation angles, thus perhaps useful as an outcome measurement in ergonomic intervention studies (before/after comparisons).

Thanks and Welcome to Bogotá

03/2010
BOGOTA, DC.