Karolinska Institutet

Institutionen för folkhälsovetenskap

Measurements of physical workload with special reference to energy expenditure and work postures

AKADEMISK AVHANDLING
som för avläggande av teknologie doktorsexamen vid Karolinska Institutet offentligen försvaras i Rehabsalen, plan 1, Norrbacka, inom Karolinska Universitetssjukhusets område, Solna

Fredagen den 18 februari, 2011, kl. 09.00

av
Eva Bernmark
Civilingenjör

Huvudhandledare:
Docent Christina Wiktorin
Karolinska Institutet
Institutionen för folkhälsovetenskap

Bihandledare:
Docent Mikael Forsman
Karolinska Institutet
Institutionen för folkhälsovetenskap

Doktor Ola Leijon
Karolinska Institutet
Institutionen för folkhälsovetenskap

Fakultetsopponent:
Docent Göran Hägg
Högskolan i Gävle
Centrum för belastningsskadeforskning

Betygsnämnd:
ProfessorAnna-Lisa Osvalder
Chalmers tekniska högskola
Institutionen för produkt och produktionsutveckling

Docent Michael Sjöström
Karolinska Institutet
Institutionen för biovetenskaper och Näringslära

Professor Suzanne Werner
Karolinska Institutet
Institutionen för molekylär medicin och kirurgi

Stockholm 2011

ABSTRACT

Background: There is a need in preventive ergonomics for accurate and valid methods of quantifying exposure to physical workload.

Aims: Two technical instruments were evaluated for quantifying occupational physical workloads: 1) A heart rate (HR) monitor system to measure energy expenditure and 2) An inclinometer system based on triaxial accelerometers to measure work postures.

Methods: HR measurements in work with light to moderate energy expenditure were validated against direct oxygen consumption (VO_2) measurements (Study I) performed at 25 workers' workplaces. Two data-analysis methods were tested: 1) direct HR measurements expressed in beats per minute (bpm), and 2) HR measurements combined with individual exponential HR-VO_2 equations. Study II used HR measurements to see if work tasks with high energy expenditure could be differentiated from work tasks with light to moderate expenditures. Five bicycle messengers participated in that study. The inclinometer system was validated against an optoelectronic system, The MacReflex system (Study III). Six subjects' arm positions and arm movements were examined. The inclinometer system was also evaluated at 10 computer-workers workplaces to examine whether it could discriminate between head movements performed when working with two similar computer work tasks (Study IV).

Results: HR measurements combined with individual exponential HR-VO_2 equations better measured physical workload than direct (bpm) HR measurements (Study I). Individual exponential HR-VO_2 equations created from submaximal bicycle ergometer tests without VO_2 measurements were almost as good as HR-VO_2 equations created from maximum cycle ergometer tests with VO_2 measurements. The HR measurements combined with exponential HR-VO_2 equations could differentiate between work tasks with high and work tasks with light to moderate energy expenditure (Study II).
The tested inclinometer system measured the degree of inclination for all arm positions and movements with high precision (Study III). The inclinometer system was unable to measure the direction on the inclination of the arm in relation to the trunk, as the system cannot measure rotations about the longitudinal axis of the arm. The inclinometer system (Study IV) could detect small differences in head motions between two similar computer work tasks. It would have been impossible to register these small differences with any observation method.

Conclusions:

- Heart-rate measurements in combination with individual exponential HR-VO_2 equations can be used to discriminate between works involving light, moderate or heavy energy expenditure.
- Individual's exponential HR-VO_2 equation can be established from submaximal cycle ergometer tests without measurement of oxygen consumption.
- The tested inclinometer system can be used to measure the degree of inclination of body segments.
- The tested inclinometer system cannot be used to measure the direction of the inclination of a body segment in relation to the adjacent body segment.
- A triaxial accelerometer as well as a uniaxial accelerometer can be used to discriminate between two different degrees of static work, in terms of accelerations.

Keywords: Exposure assessment, physical workload, energy expenditure, posture, heart rate, accelerometer, inclinometer, field measurement

ISBN 978-91-7457-227-8