POSTECH
포항공과대학교

Ergonomic Design Technology Lab

An analysis of repetitiveness measures and measurement/analysis methods for hand-intensive tasks

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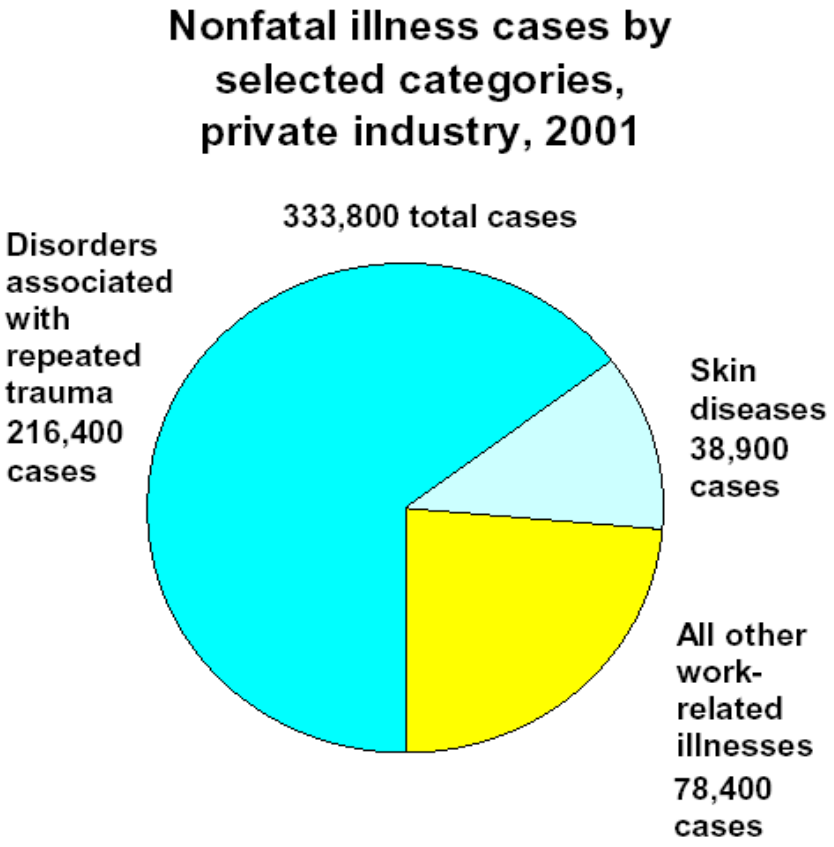
Agenda

- Background
- Objective
- Repetitiveness measures
- Measurement/analysis methods
- Conclusion

Nonfatal illness cases - 2001

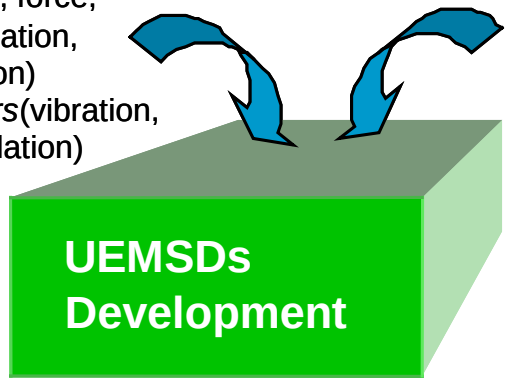


- 65% of nonfatal illnesses were related to repetitive trauma disorders (BLS, 2002)

UEMSDs development

Physical Factors
- *task factors* (posture, force, repetitiveness, duration, stress concentration)
- *environmental factors* (vibration, temperature, ventilation)

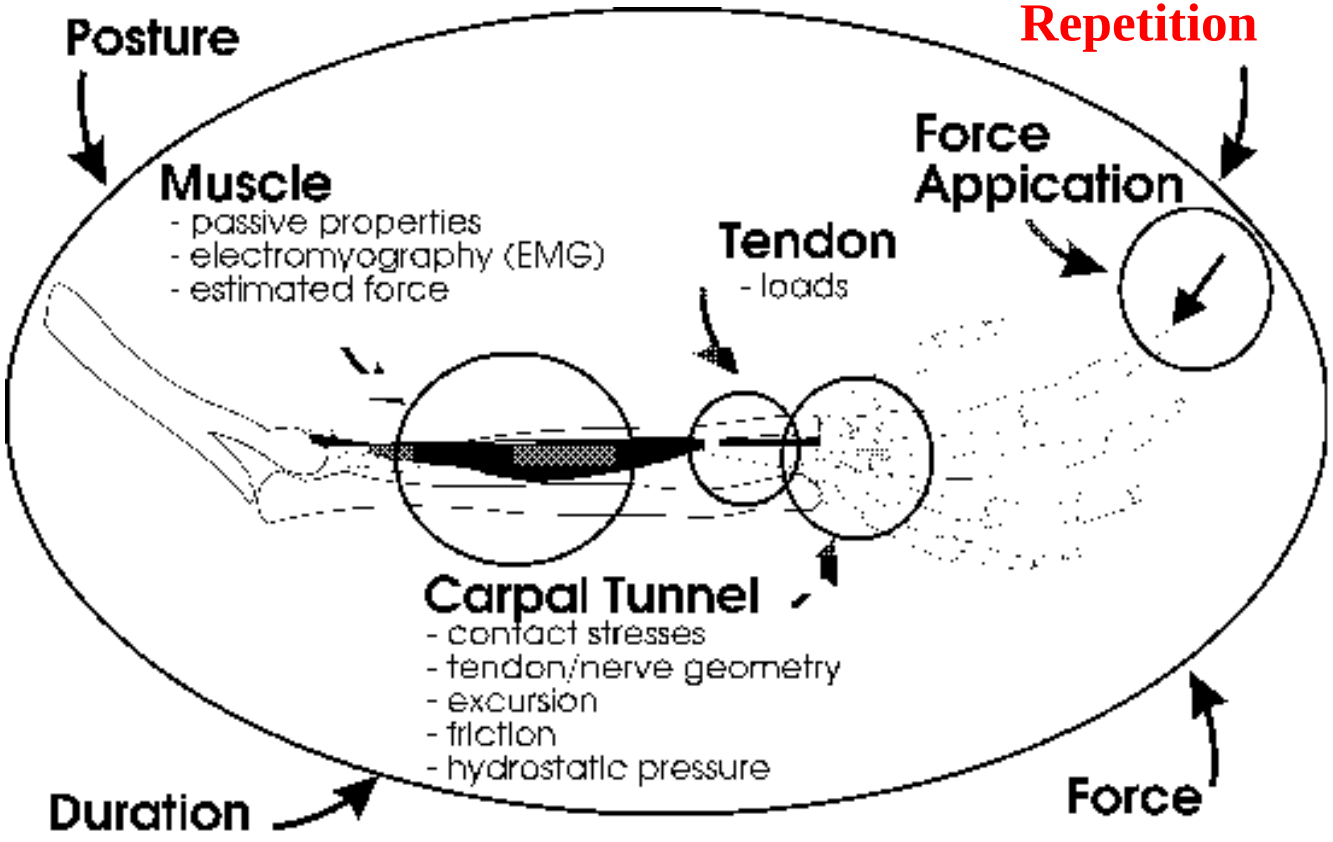
Psychosocial Factors
- *physical demands* (time pressure, attention demand, monotony, responsibility)
- *organization factors* (autonomy, worker participation, job security)
- *social support* (family support, colleague support, safety awareness)



Personal Factors
- *sociodemographic factors* (age, gender, exercise, hobby)
- *medical history*
- *anthropometric factors* (wrist size, obesity)

- **Risk factors of upper-extremity musculoskeletal disorders (UEMSDs) (You, 1999)**

Biomechanical model



- **Work-related upper extremity musculoskeletal disorders (Wells et al.,1994)**

Relationship between physical factors and UEMSDs

Body part *Risk factor*	Strong evidence (+++)	Evidence (++)	Insufficient evidence (+/0)	Evidence of no effect (-)
Shoulder				
Posture		●		
Force			●	
Repetition		●		
Vibration			●	
Elbow				
Repetition			●	
Force		●		
Posture			●	
Combination	●			
Hand/wrist				
Carpal tunnel syndrome				
Repetition		●		
Force		●		
Posture			●	
Vibration		●		
Combination	●			
Tendinitis				
Repetition		●		
Force		●		
Posture		●		
Combination	●			

Source: NIOSH (1997)

Repetitiveness of hand-intensive tasks

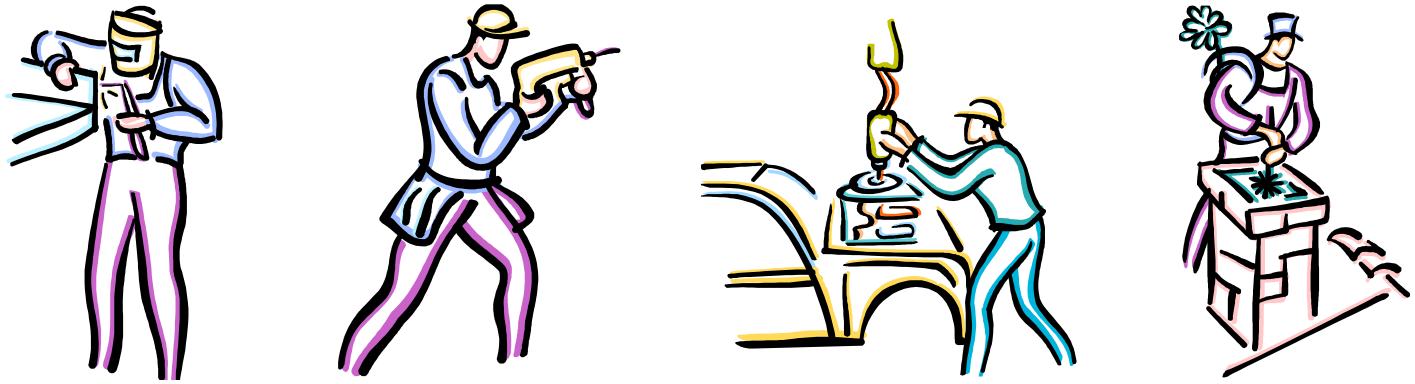
1) Repetitiveness alone could increase the risk of UEMSDs at the workplace (Colombini, 1998; Silverstein et al., 1987)
2) Repetitiveness is associated with the clinical symptoms (such as pain, weakness, clumsiness, numbness, tingling, and nocturnal symptom aggravation) of the tendon and nerve disorders at the hand and wrist (Latko et al.,1999)
3) Repetitiveness has evidence of a causal relationship with musculoskeletal disorders at the shoulder and hand/wrist (NIOSH, 1997)

Objective

- To survey and compare repetitiveness assessment methodologies for hand-intensive tasks

  ① Establishing a hierarchy of repetitiveness measures

  ② Summarizing measurement methods and analysis techniques



Process for literature survey (from 1997 to 2002)

- Scientific database systems
  - ScienceDirect® *(www.sciencedirect.com*)
  - Ingenta Select (*www.ingentaselect.com*)
  - MEDLINE (*www4.infotrieve.com*)
- Search keyword - combination of terminologies
  - Terminology for repetitiveness: repetition, repetitive, and repetitious
  - Terminology for upper extremity: hand, wrist, finger, elbow, shoulder, forearm, arm, manual, and upper limb
  - Terminology for task: work, job, motion, and movement
- 31 studies were screened by reviewing the abstracts of the searched studies

Classification of repetitiveness measures

Dimension	Analysis scope	Measure
Time	Work cycle	Overall work cycle time Fundamental work cycle time
Frequency	Work cycle	Overall work cycle frequency Fundamental work cycle frequency
	Body region	Finger movement frequency Hand/wrist movement frequency Forearm/elbow movement frequency Arm/shoulder movement frequency
	Force exertion	Power force exertion frequency Pinch force exertion frequency

- **The work cycle time and frequency measures are convertible to each other**

Time dimension vs. frequency dimension

$$f = \frac{L}{W + R}$$

L(2 hours), *W*(50 minutes), *R*(10 minutes)

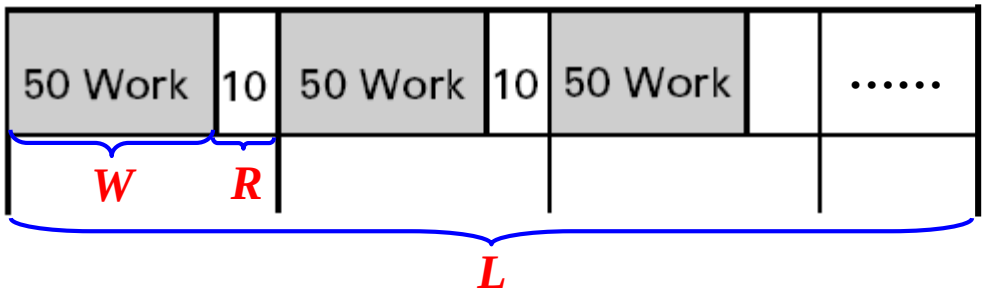
f = 120/(50+10) = 2

where: *f* = frequency of overall (or fundamental) work cycle

L = length of a time period

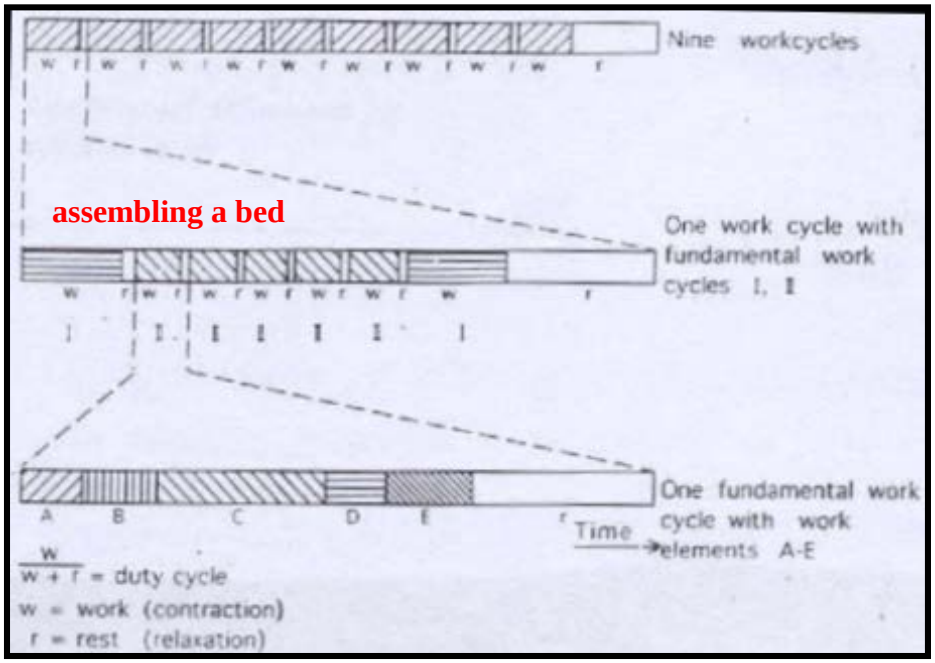
W = overall (or fundamental) work cycle time

R = rest time between overall (or fundamental) work cycle



Work cycle vs. Fundamental work cycle

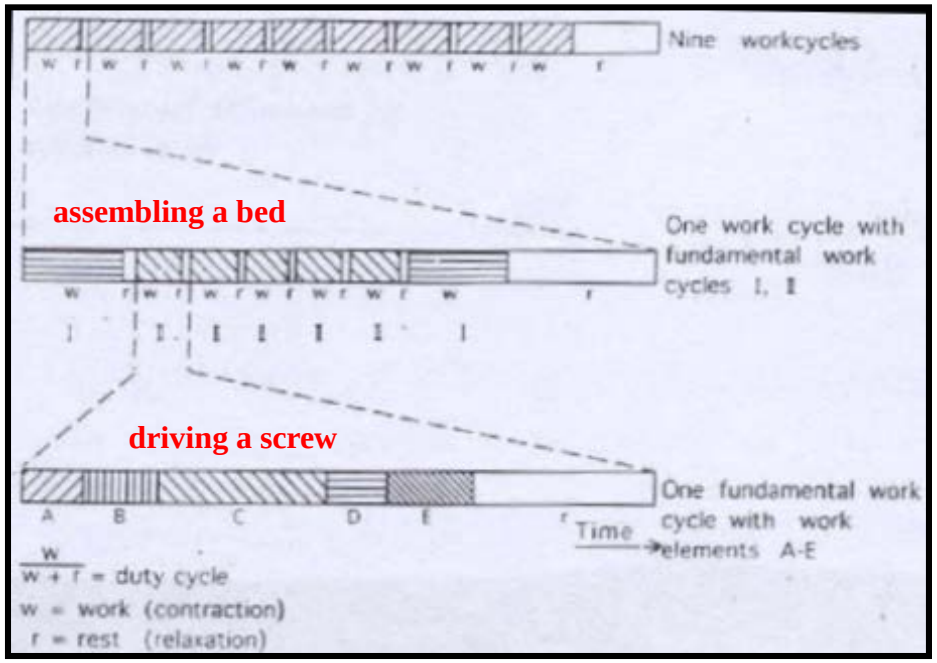
- Work cycle (= overall work cycle)
  - A sequence of action cycles, that repeats itself over and over, always the same (Colombini, 1998)
  - e.g., assembling a bed, joining a door to a closet, or fitting a gas equipment to a sink in a trailer assembly task (Hakkanen et al., 1997)



Adapted from Kilbom (1994)

Work cycle vs. Fundamental work cycle

- Fundamental work cycle
  - A sequence of steps that repeated themselves within the work cycle (Silverstein et al., 1986)
  - e.g., driving a screw, drilling, stapling, gluing or lifting in each work cycle (Hakkanen et al., 1997)



Adapted from Kilbom (1994)

Study classification by repetitiveness measures

Measure			Study (No. studies)	
Time	Work cycle	Overall work cycle time	BK, CD, CH1, KR, LW-2, SP, TF, JB-2, YT-2, **YT-3**	(10)
		Fundamental work cycle time		(0)
Frequency	Work cycle	Overall work cycle frequency	CD, YT-1, YT-2	(3)
		Fundamental work cycle frequency	CD, HM	(2)
	Body region	Finger movement frequency	LW-1, LW-2, YM-1, YM-2	(4)
		Hand/wrist movement frequency	AT, BK, CE, CH2, CV, HG, HS, JB-1, JB-2, KR, LM-1, LM-2, LM-3, LT, LW-1, LW-2, MJ, SE, SM, SP, YM-1, YT-1, YT-2, **YT-3**	**(24)**
		Forearm/elbow movement frequency	HS, LW-1, YT-1, YT-2, **YT-3**	(5)
		Arm/shoulder movement frequency	HS, YT-1, YT-2, **YT-3**	(4)
	Force exertion	Power force exertion frequency	CV, LW-2, MJ, PJ	(4)
		Pinch force exertion frequency	KM	(1)
Total				(57)

- **Frequency measures used 4.7 times more frequently than time measures**
- **Hand/wrist movement frequency is most frequently used (42%)**

Various repetitiveness categories

Measure		Classification	Criterion	Source
Work cycle	Overall work cycle time	High repetitiveness	**CT[1] < 30s or same motions for CT > 50%**	Silverstein et al. (1986)
			CT < 30s	Killough and Crumpton (1996)
			CT < 2min	Rodgers (1986)
		Moderate repetitiveness	30s < CT < 2min	Killough and Crumpton (1996)
		Low repetitiveness	30s < CT < 2min and same motions for CT < 50%	Silverstein et al. (1986)
			CT > 2min	Killough and Crumpton (1996) Rodgers (1986)
	Fundamental work cycle (FWC) time	High repetitiveness	**FCT[2] < 2s**	Hansson et al. (1996)
			FCT < 30s	Konz (1990)
		Moderate repetitiveness	2s < FCT < 10s	Hansson et al. (1996)
		Low repetitiveness	FCT > 10s	Hansson et al. (1996)
			FCT > 30s	Konz (1990)

(Notes) [1]Cycle time; [2]Fundamental cycle time

Various repetitiveness categories (cont'd)

Measure		Classification	Criterion	Source
Body region	Finger movement frequency	High repetitiveness	NM > 200 motions/min	Kilbom (1994)
		Low repetitiveness	NM < 200 motions/min	
	Hand/wrist movement frequency	High repetitiveness	**NM > 20 motions/min**	Carey and Gallwey (2002) Yen and Radwin (2000) Li and Buckle (1998)
			NM > 15 motions/min	Lin et al. (1997)
			NM > 33.3 motions/min	Wick (1994)
			NM > 4 motions/min	Hignett and McAtamney (2000) McAtamney and Corlett (1993)
			NM > 10 motions/min	Kilbom (1994)
		Moderate repetitiveness	10 < NM < 20 motions/min	Carey and Gallwey (2002) Yen and Radwin (2000) Li and Buckle (1998)
			4 < NM < 15 motions/min	Lin et al. (1997)
			25 < NM < 33.3 motions/min	Wick (1994)
		Low repetitiveness	NM < 10 motions/min	Carey and Gallwey (2002) Yen and Radwin (2000) Li and Buckle (1998) Kilbom (1994)
			NM < 4 motions/min	Lin et al. (1997) Hignett and McAtamney (2000) McAtamney and Corlett (1993)
			NM < 25 motions/min	Wick (1994)

Various repetitiveness categories (cont'd)

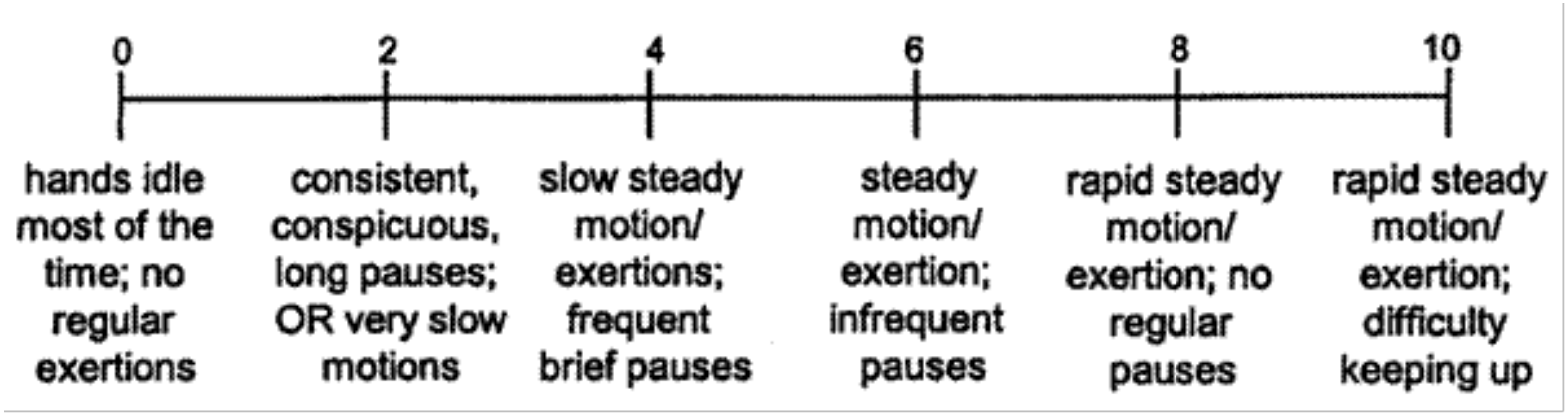
Measure		Classification	Criterion	Source
Body region	Forearm/ elbow movement frequency	High repetitiveness	**NM[1] > 4 motions/min**	Hignett and McAtamney (2000) McAtamney and Corlett (1993)
			NM > 10 motions/min	Kilbom (1994)
		Low repetitiveness	NM < 4 motions/min	Hignett and McAtamney (2000) McAtamney and Corlett (1993)
			NM < 10 motions/min	Kilbom (1994)
	Arm/ shoulder movement frequency	High repetitiveness	**NM > 4 motions/min**	Hignett and McAtamney (2000) McAtamney and Corlett (1993)
			NM > 10 motions/min	Kilbom (1994)
		Moderate repetitiveness	2.5 < NM < 10 motions/min	Kilbom (1994)
		Low repetitiveness	NM < 4 motions/min	Hignett and McAtamney (2000) McAtamney and Corlett (1993)
			NM < 2.5 motions/min	Kilbom (1994)
Force exertion	Power force exertion frequency	High repetitiveness	NE[2] > 20 exertions/min	Moore and Garg (1995)
		Moderate repetitiveness	4 < NE < 20 exertions/min	
		Low repetitiveness	NE < 4 exertions/min	

(Notes) [1]Number of motions; [2]Number of exertions

- **Need to establish a quantitative guide to determine the repetitiveness level for each measure by integrating previous findings**

Measurement Methods and Analysis Techniques

Classification		Example	Note
Measurement method	Objective method	Stopwatch, video, electrogoniometer, electromyography (EMG)	Electrogoniometer: measuring angular movements at the joint of interest
	Subjective method	Categorical scale, checklist, **visual analogue scale (VAS)**	VAS: consisting of a line with numbers and verbal anchors



Adapted from Latko et al. (1999)

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	Subjective method	Categorical scale, checklist, visual analogue scale (VAS)	VAS: consisting of a line with numbers and verbal anchors
Analysis technique	Statistical technique	Mean, standard deviation	Mean: most popular technique
	Spectral technique	Spectral analysis, mean power frequency (MPF)	MPF: average frequency weighted by power

Conclusion

- Analysis of repetitiveness assessment methodology
  - Time and frequency measures are convertible to each other
  - Time measures don't exist for body region and force exertion
    - They are difficult and/or impractical to measure and analyze times of individual motions and force exertions.
  - Frequency measures use more frequently than time measures
    - Hand/wrist movement frequency is most popular

Significance and further study

- Significance
  - To facilitate effective integration of repetitiveness research findings
  - To help practitioners select the appropriate methodology in repetitiveness assessment
- Further study
  - Need a quantitative guide to determine the repetitiveness level
    - Criteria for a high level of repetitiveness should decrease for finger, hand/wrist, forearm/elbow, and arm/shoulder in order (Kilbom, 1994)

Q & A