PHYSIOLOGICAL LIMITATIONS IN ASCENDING STAIRS EVACUATION

Amitava Halder 1, Kalev Kuklane1, Chuansi Gao 1,

Thermal Environment Laboratory,

Division of EAT, Department of Design Sciences

Johan Norén 2, Mattias Delin 3,

Enrico Ronchi 1, Silvia Arias 1,

Karl Fridolf 4

1: LU (Lund, Sweden), 2: BRIAB (Stockholm, Sweden), 3. DeBRAND (Stockholm, Sweden), 4: SP (Lund, Sweden)

Physiological challenges in "long Ascending Stairs"

"Long stair ascent is a physically challenging and demanding task regarding leg Muscle dynamics and Cardiovascular capacities".

Exertion to Exhaustion

»1. Oxygen or metabolic capacity

»2. Muscular repetitive force production ability

ASCENDING SPEED

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Specific aims

- To investigate the relationship between muscle activity and oxygen consumption during ascending stairs.

- To explore whether muscle fatigue or cardiovascular capacity is a limiting factor which determines the evacuation speed, flow.

Ascending capacity or endurance in stairs

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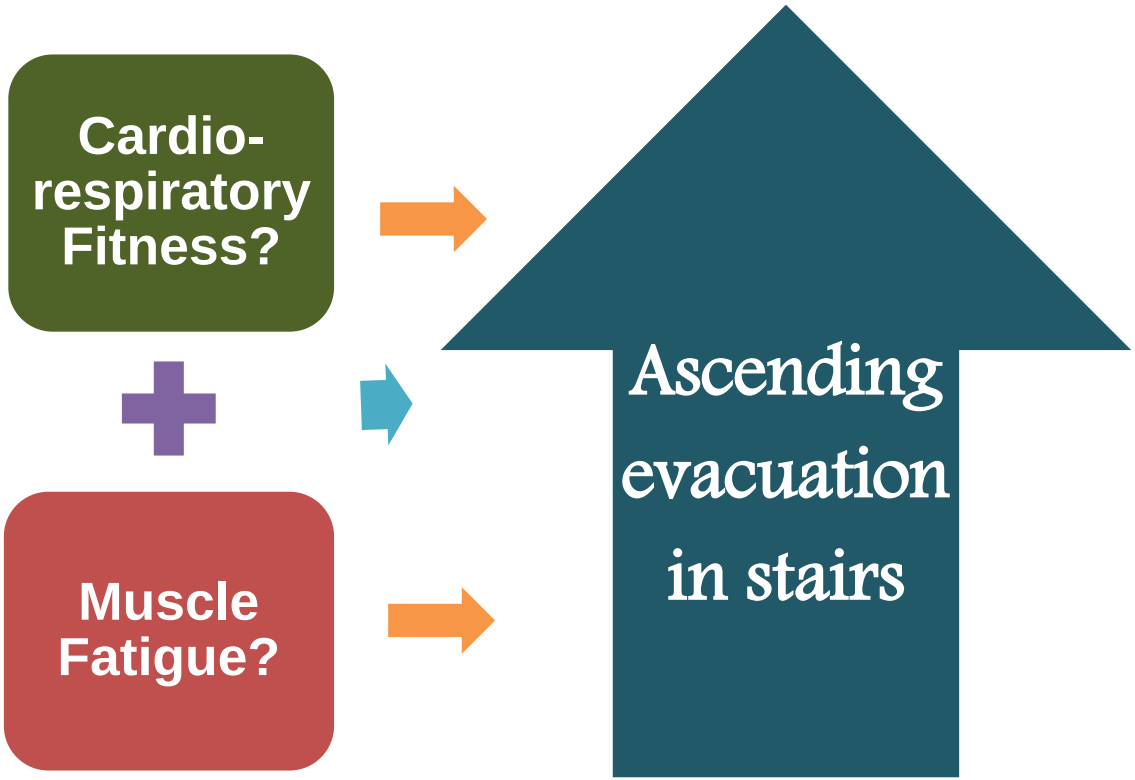
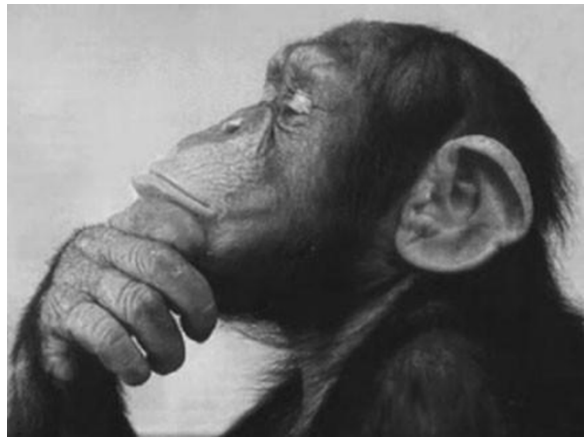
Co-relation / Limiting factor?





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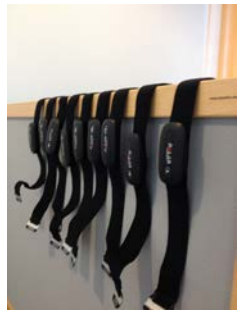
Instrumentations

- Metamax II: VO_2 Consumption.
- Polar Team 2: Heart Rate.
- Sony camera: Climbing speed
- Electromyography:4 muscles
- RPE (Borg Scale)



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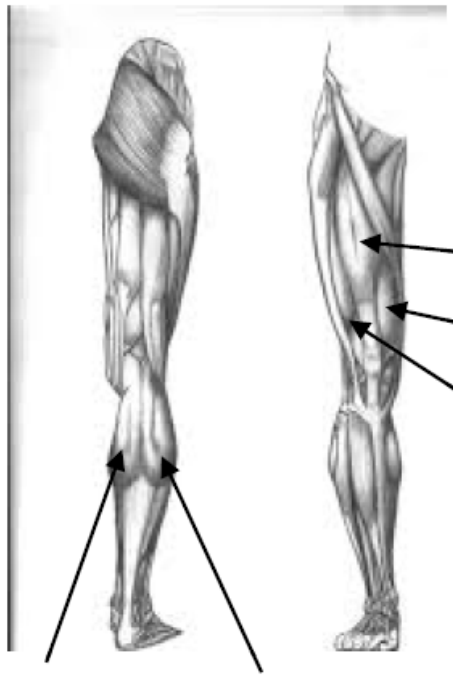
Measured Muscles in EMG



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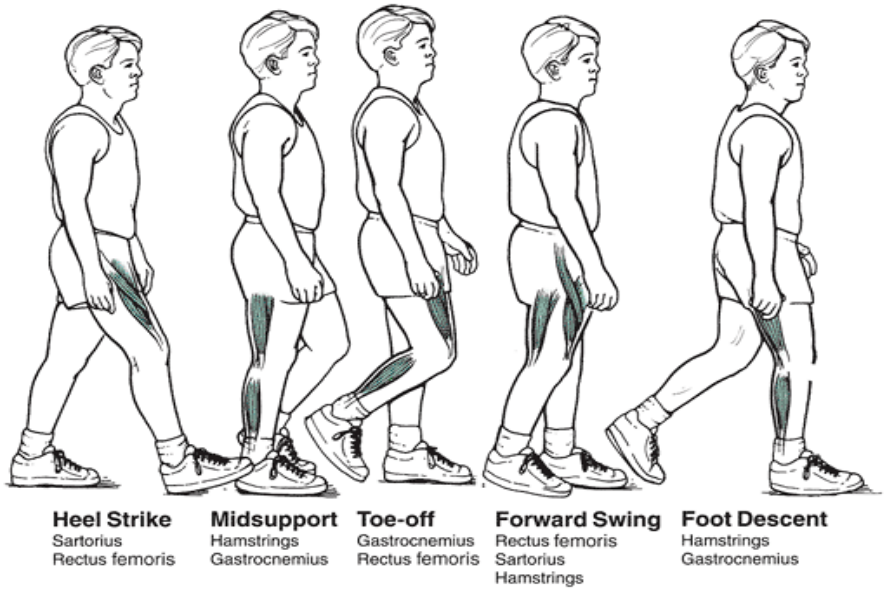
Muscle Factors

- Climbing strategies
  - Single or double step
  - High to low speed
- **Type of muscles recruitment**
  - Slow type i-Oxydative
  - Mixed type i & ii-Oxy-Glycolytic
  - Fast, type ii-Glycolytic
- **The two-joint muscles**



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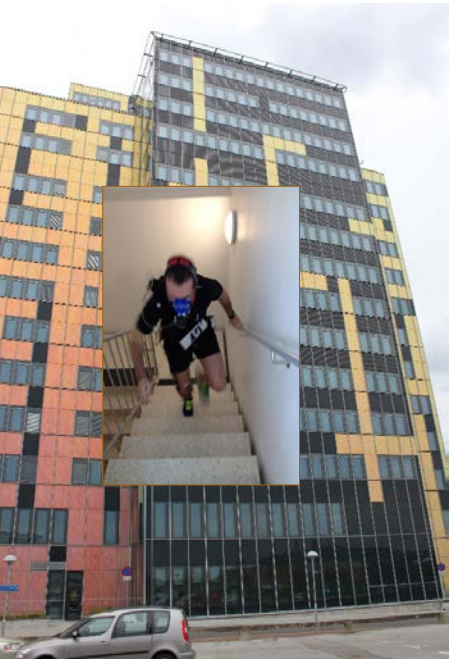
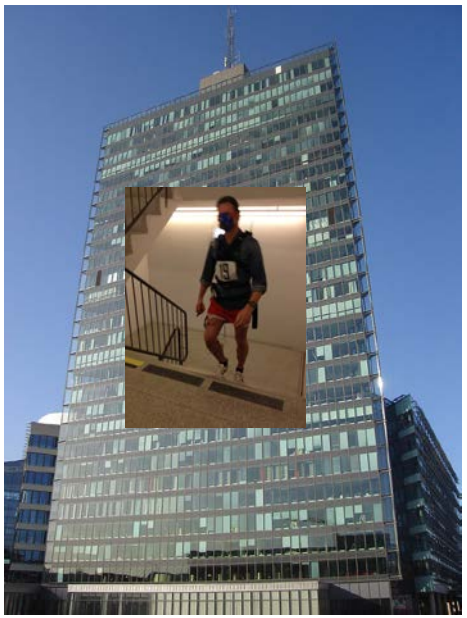
Methods: Full scale experiments

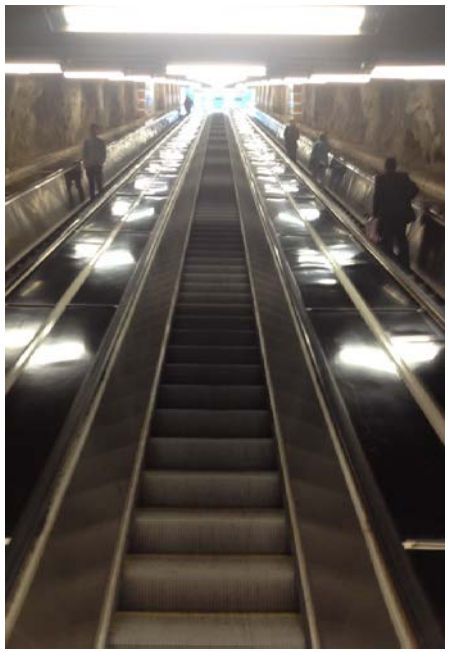
12 floors building
(268 steps)



30 floors building
(677 steps)



Metro station
Height 33 m



Laboratory study in Lund
Stairmaster SM5

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Participants anthropometry at a glance Mean (SD)

sEMG

Experiments Phase	No. of Subjects	Male : Female	Age (years)	Height (m)	Weight (kg)	Body area (m^2)
12 floor	12	8:4	35.6 (9.7)	1.74 (0.06)	72.9 (11.9)	1.87 (0.2)
30 floor	9	6:3	33.2 (7.3)	1.75 (0.05)	72.5 (12.5)	1.86 (0.1)
VästraSkogen	N/A	N/A	N/A	N/A	N/A	N/A
Laboratory study	23	13:10	33.5 (11.0)	1.73 (0.07)	74.6 (18.3)	1.87 (0.2)

VO2

Experiments Phase	No. of Subjects	M vs F	Age (years)	Height (m)	Weight (kg)	Body area (m^2)
12 floor	48	27:21	32.5 (9.3)	1.76 (0.08)	73.8 (13.9)	1.89 (0.2)
30 floor	29	18:11	31.8 (7.0)	1.73 (0.06)	70.8 (13.9)	1.83 (0.2)
VästraSkogen	A	A	A	A	A	A
Laboratory study	25	13:12	35.3(12.3)	1.72 (0.07)	74.4 (17.6)	1.86 (0.2)

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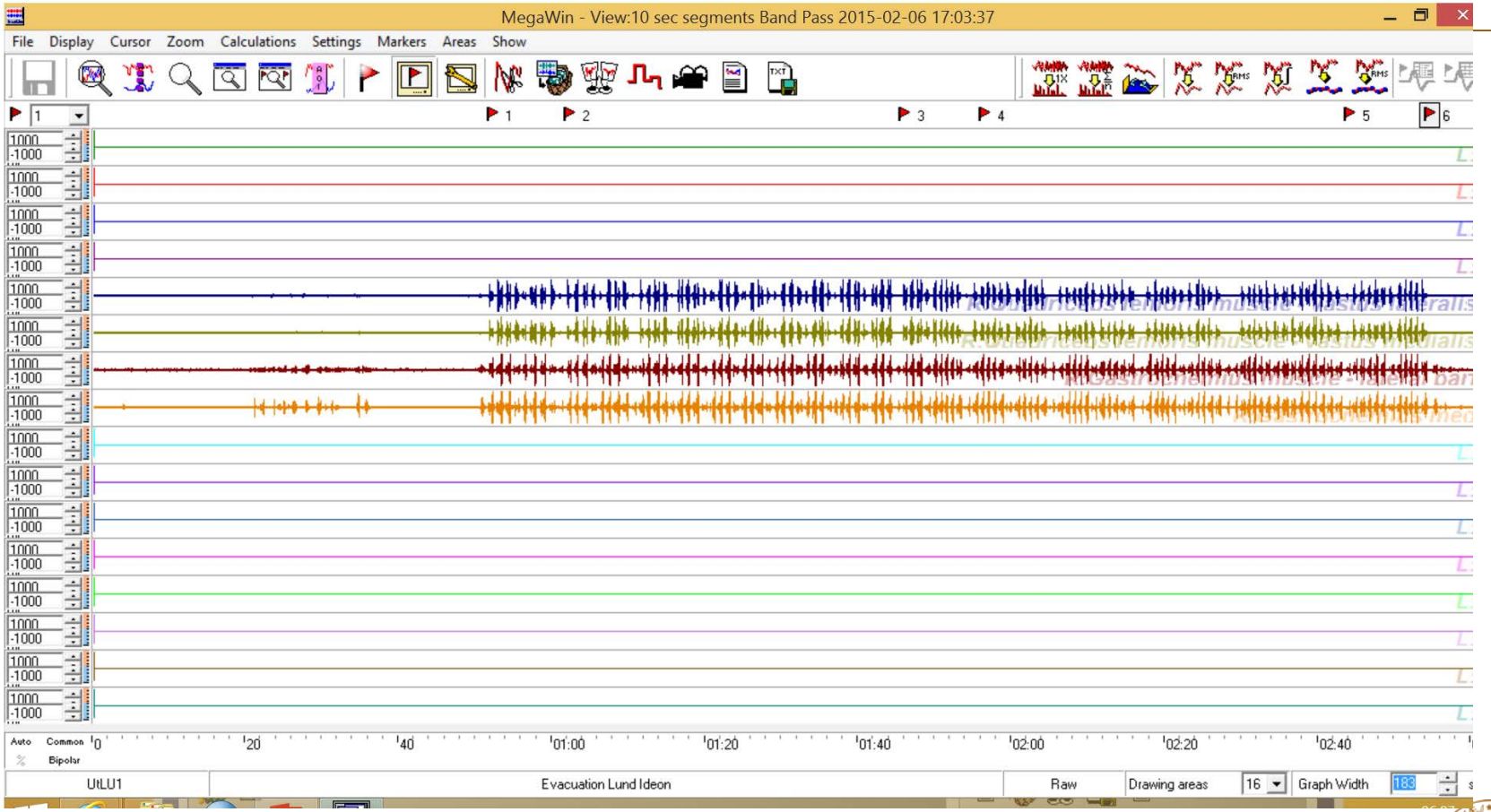
Surface EMG Muscle Activity: Fatigue



sEMG Fatigue Parameters: Frequency and Amplitude

Disselhorst-Klug et al., 2009 and Cifrek et al., 2009

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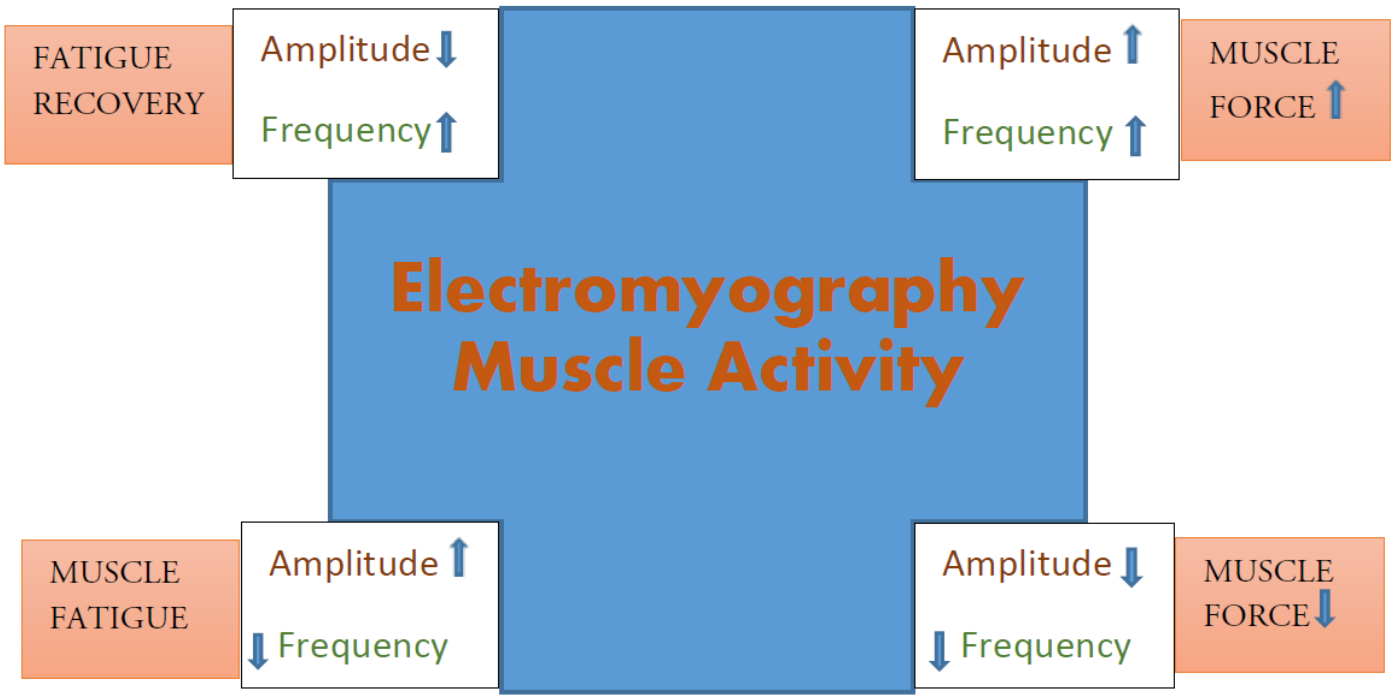
Muscle Force vs Fatigue



Farina et al., 2002 & Cifrek et al., 2009.

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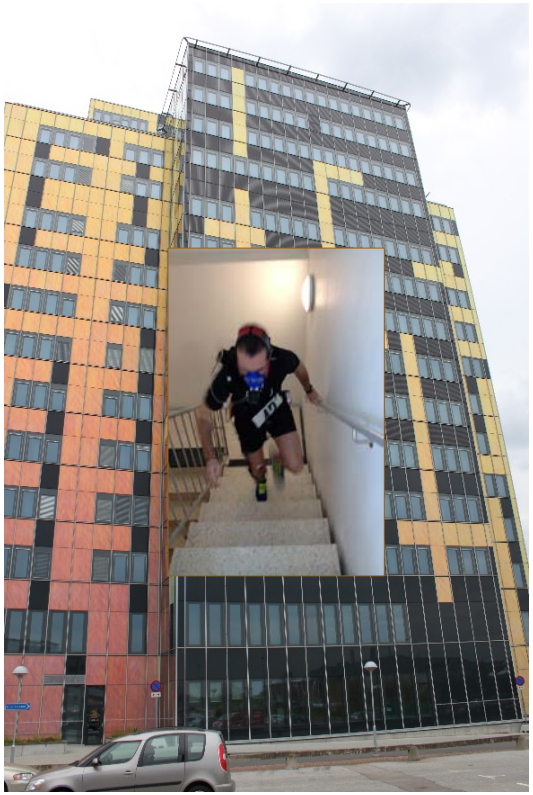
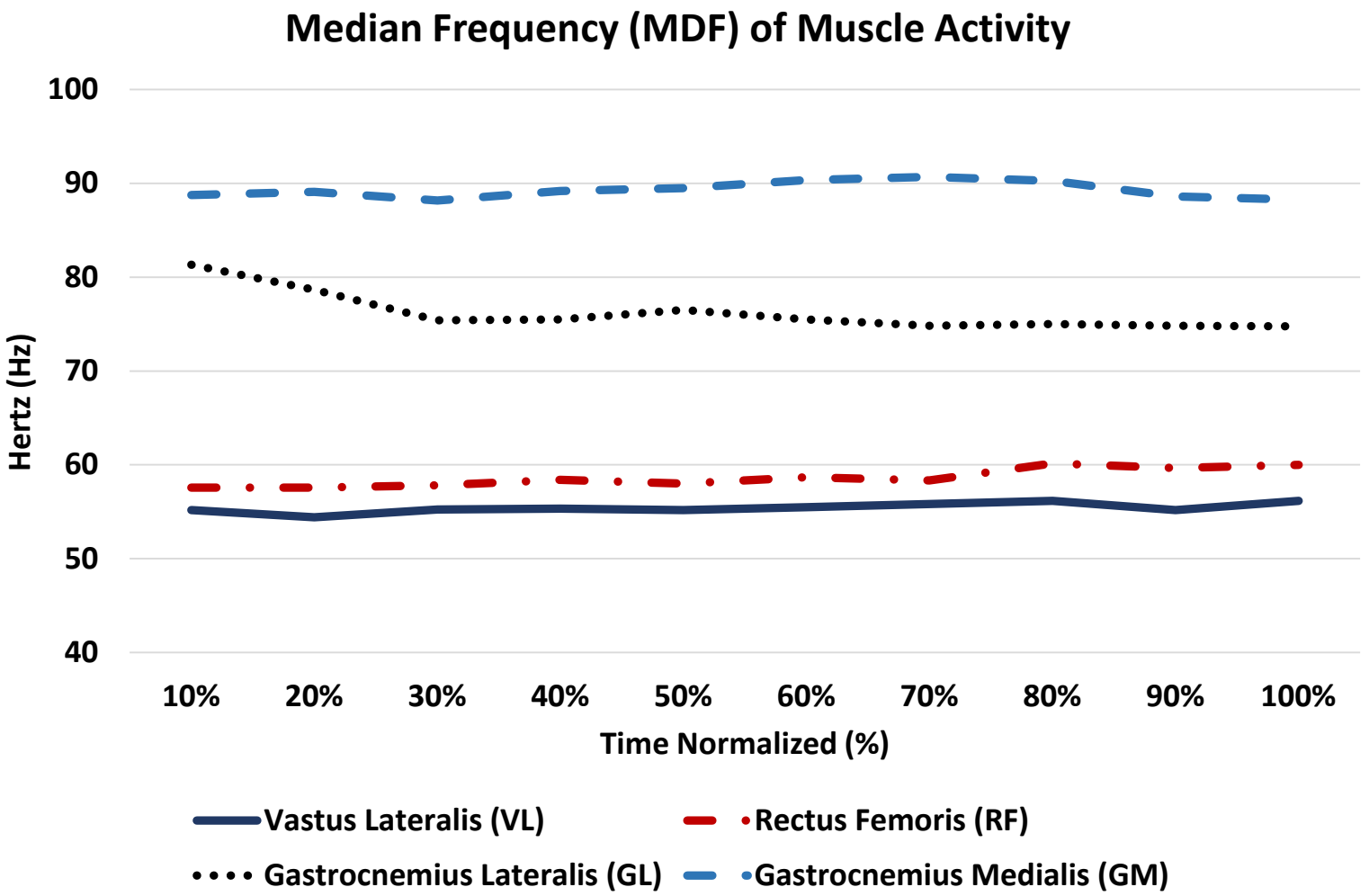


Lund Ideon Gateway (LundIG)

LUND, SWEDEN

12 FLOORS / 268 STEPS.

LundIG (n=12)
Muscle Activity: Median Frequency



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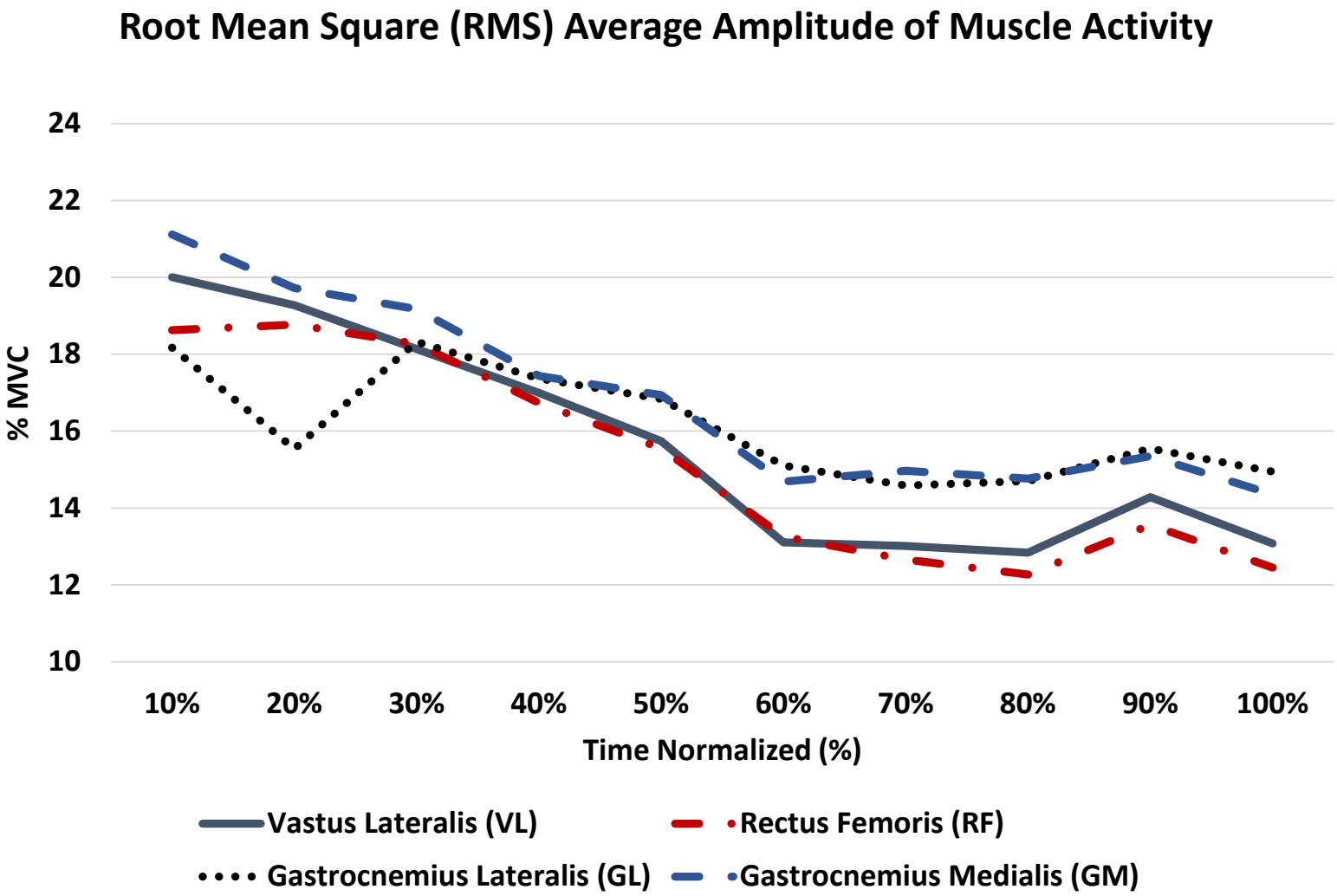
LundIG (n=12)
Muscle Activity: RMS Average Amplitude



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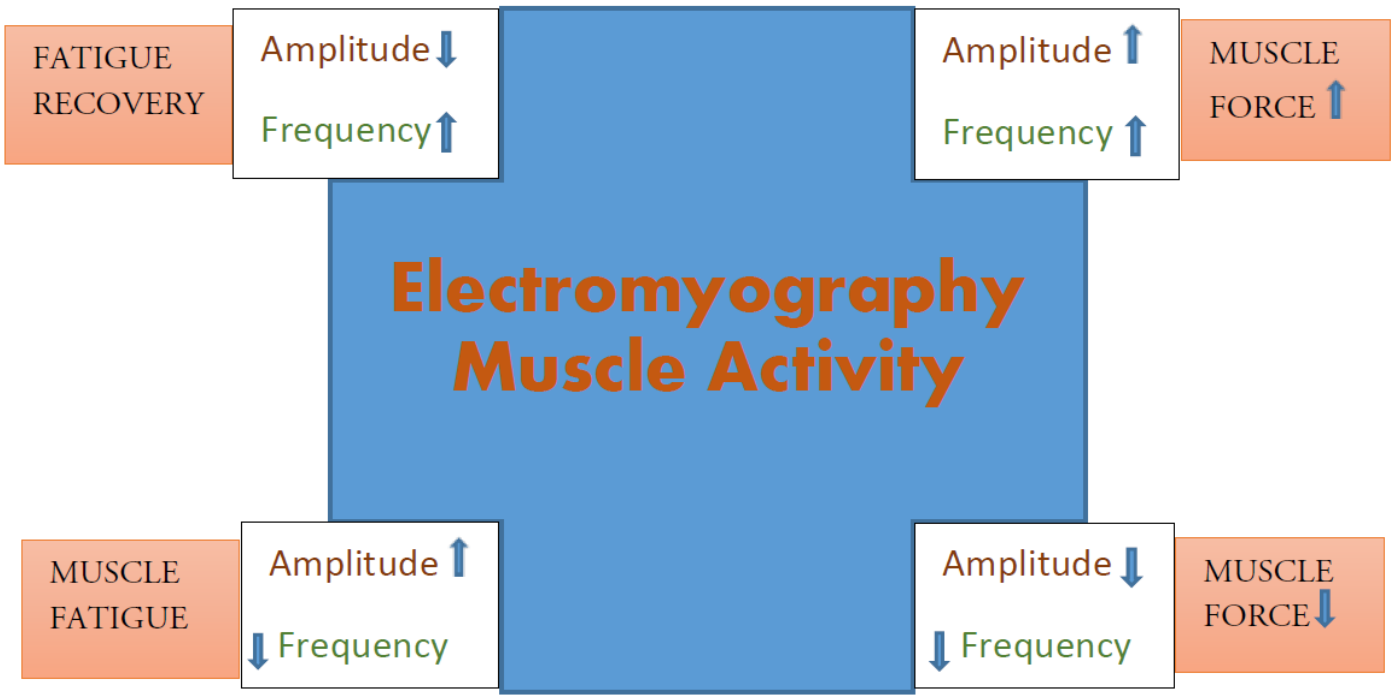
Muscle Force vs Fatigue



Farina et al., 2002 & Cifrek et al., 2009.

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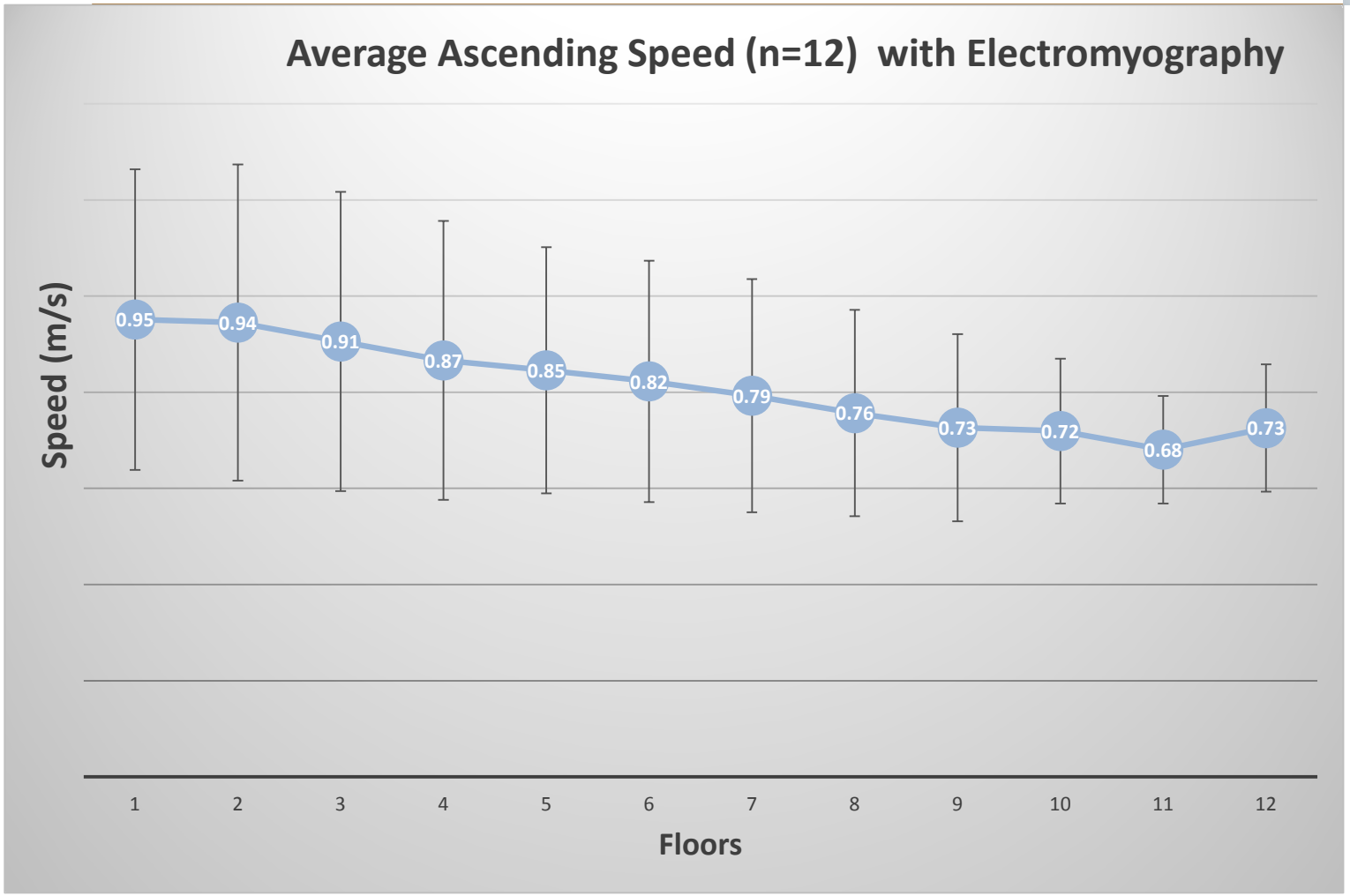
Climbing Speed : **Lund IG**



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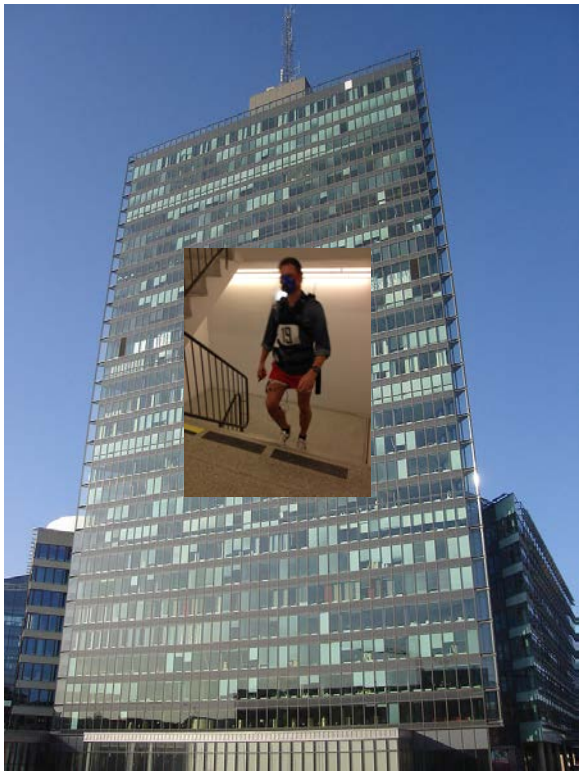
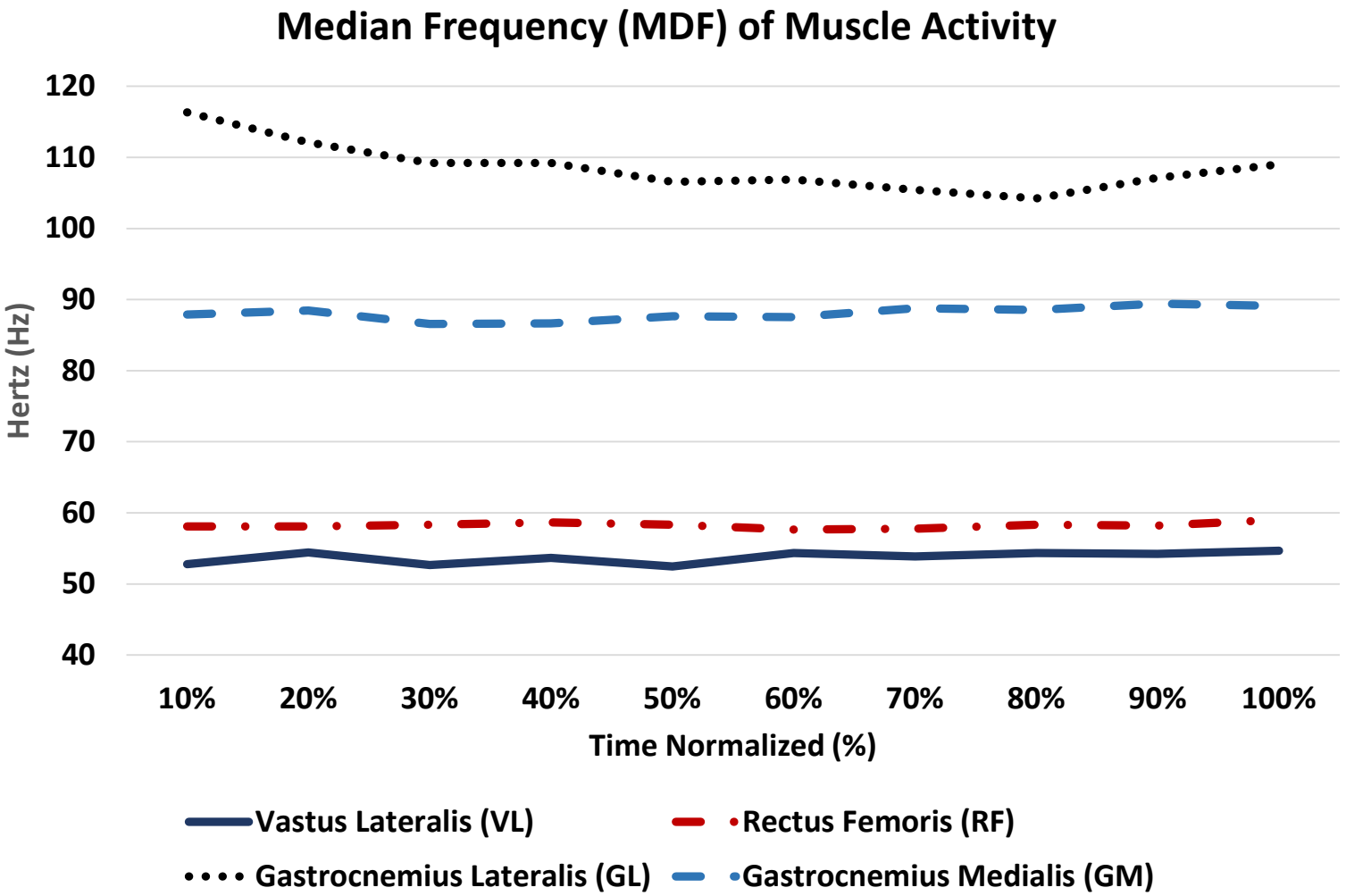


Kista Science Tower (KST)

Stockholm, sweden

30 FLOORS/ 677 STEPS.

KST (n=09)
Muscle Activity: Median Frequency



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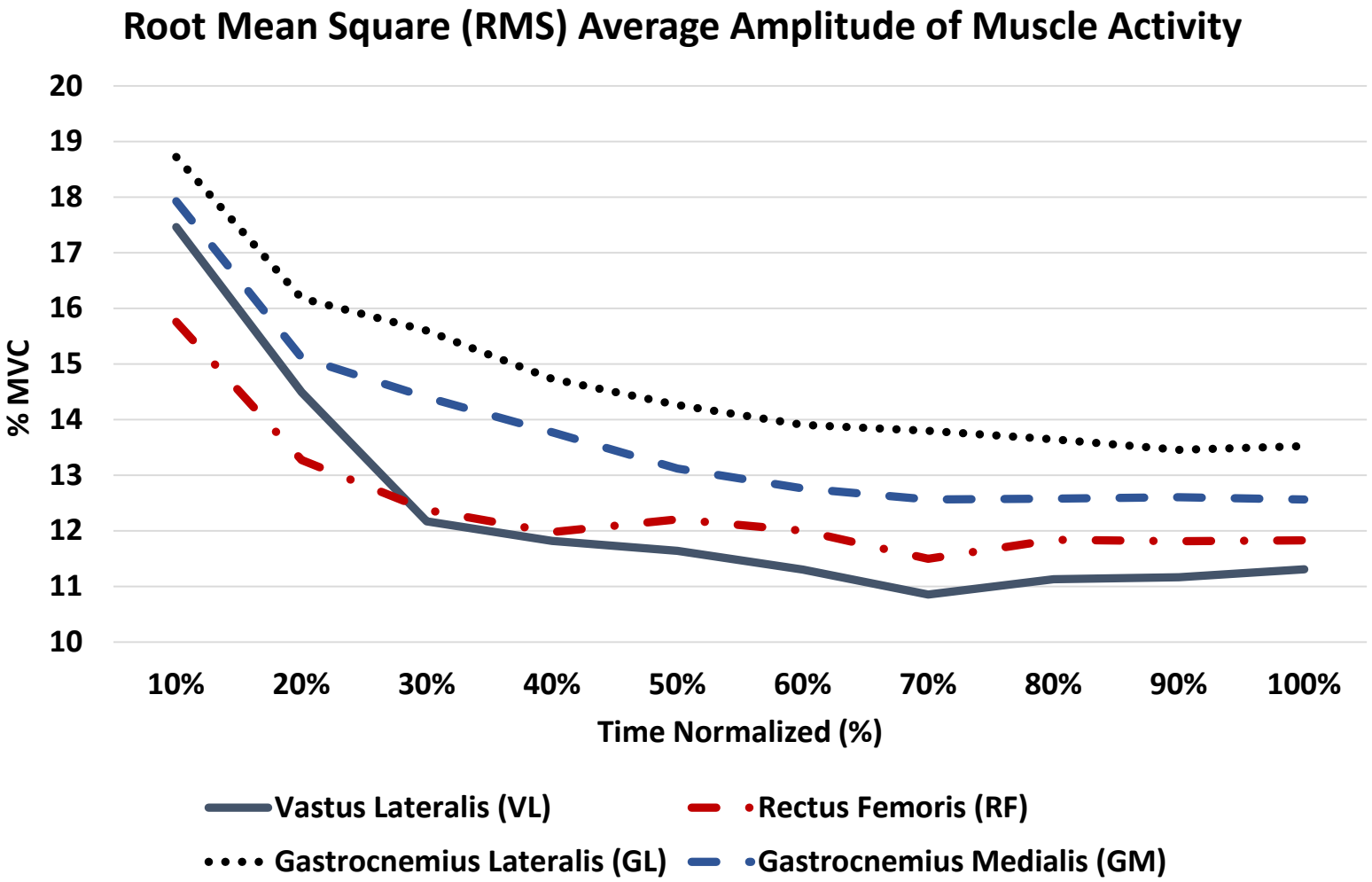
KST (n=09)
Muscle Activity: RMS Average Amplitude



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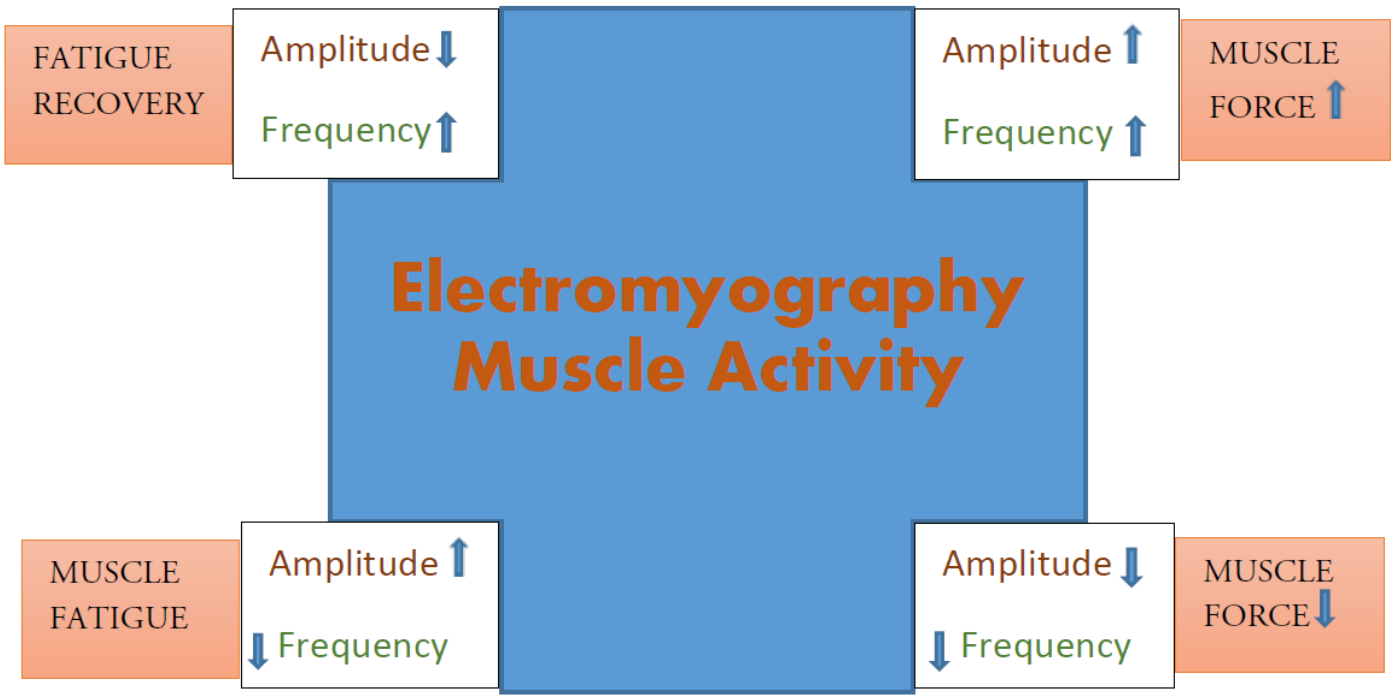
Muscle Force vs Fatigue



Farina et al., 2002 & Cifrek et al., 2009.

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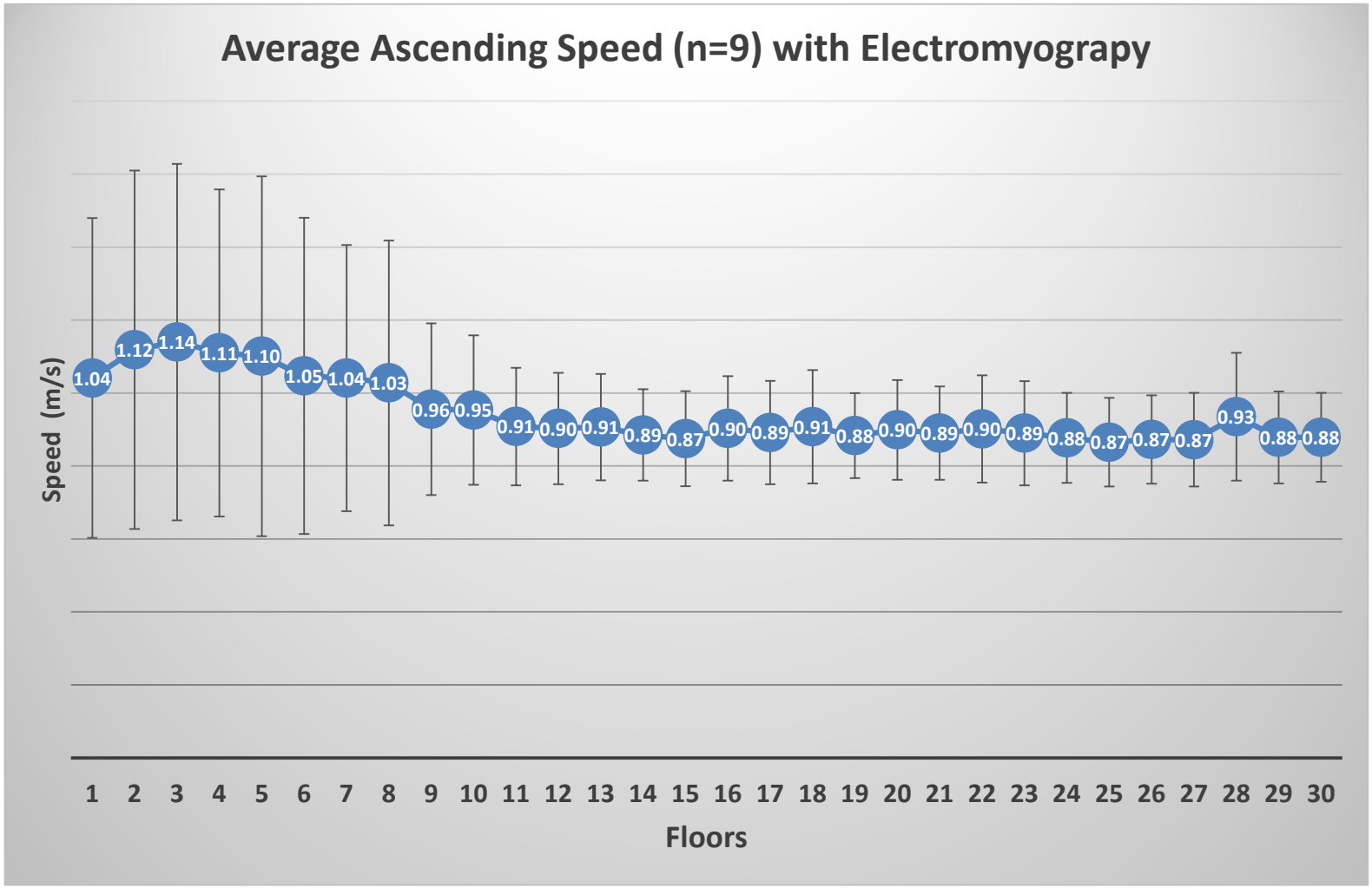
Climbing Speed : **Kista ST**



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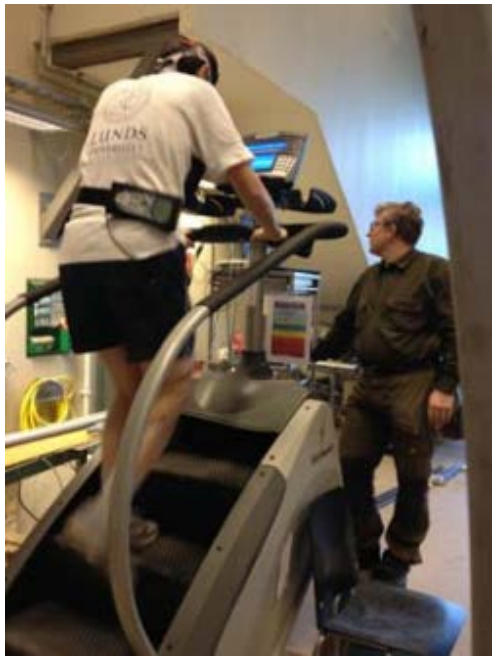
Laboratory experiments in stair machine



- VO2max test: 1 day
- 60% of VO2max related speed
- 75% of VO2max related speed
- 90% of VO2max related speed

Measurements:

Heart rate, O2 consumption & Muscle activity

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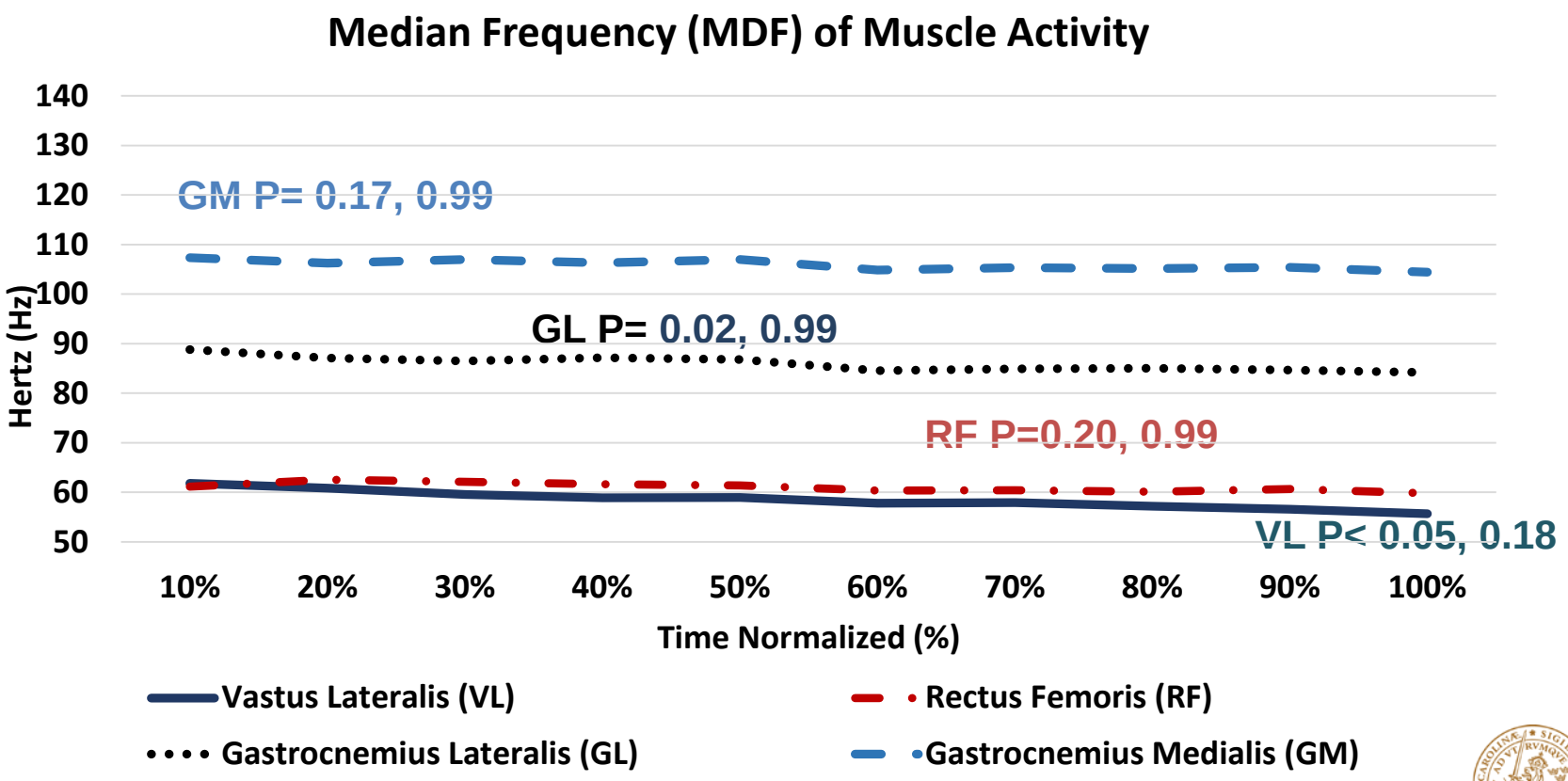
Lab (n=23)
Muscle Activity: Median Frequency



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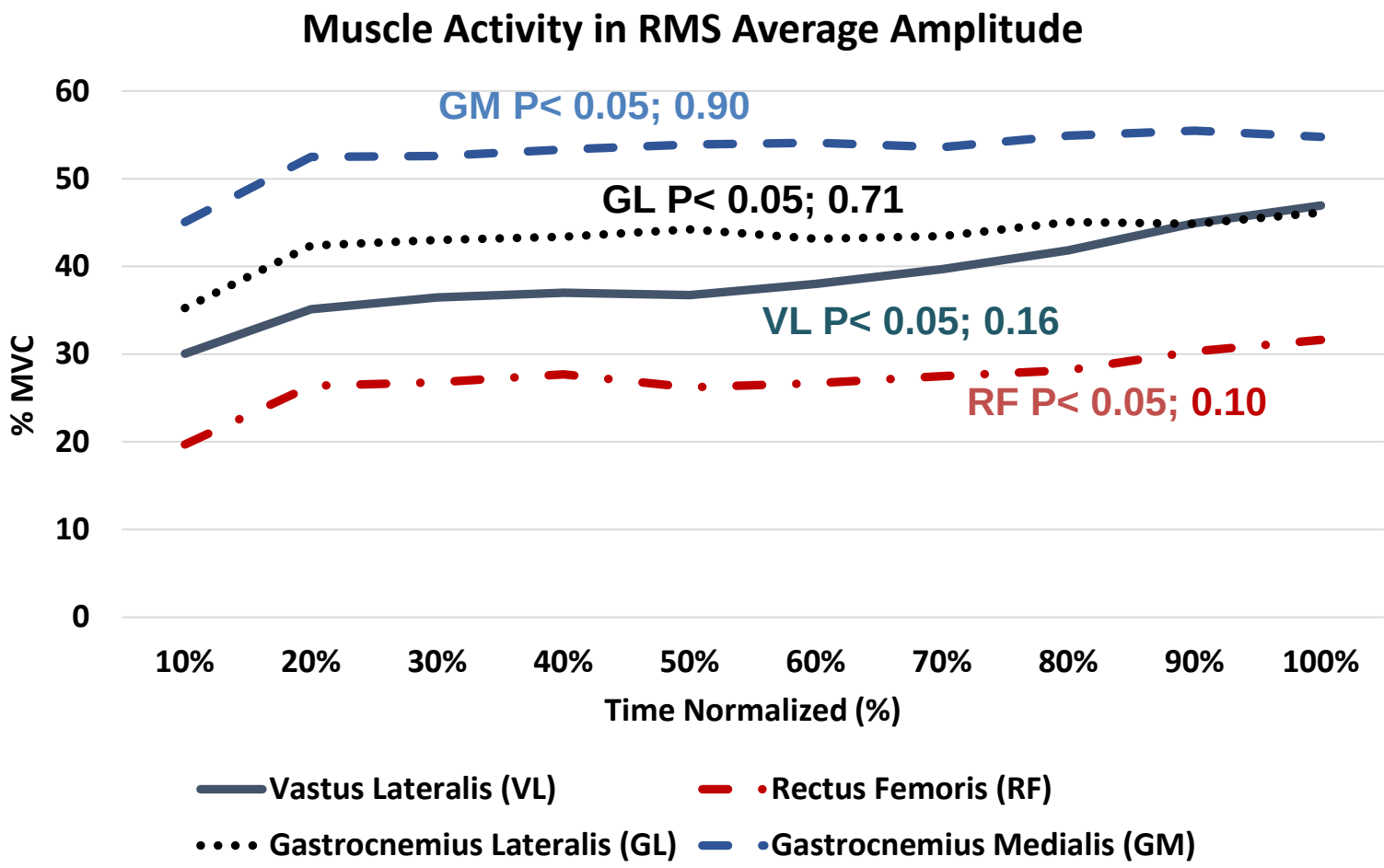
Lab (n=23)

Muscle Activity: RMS Average Amplitude



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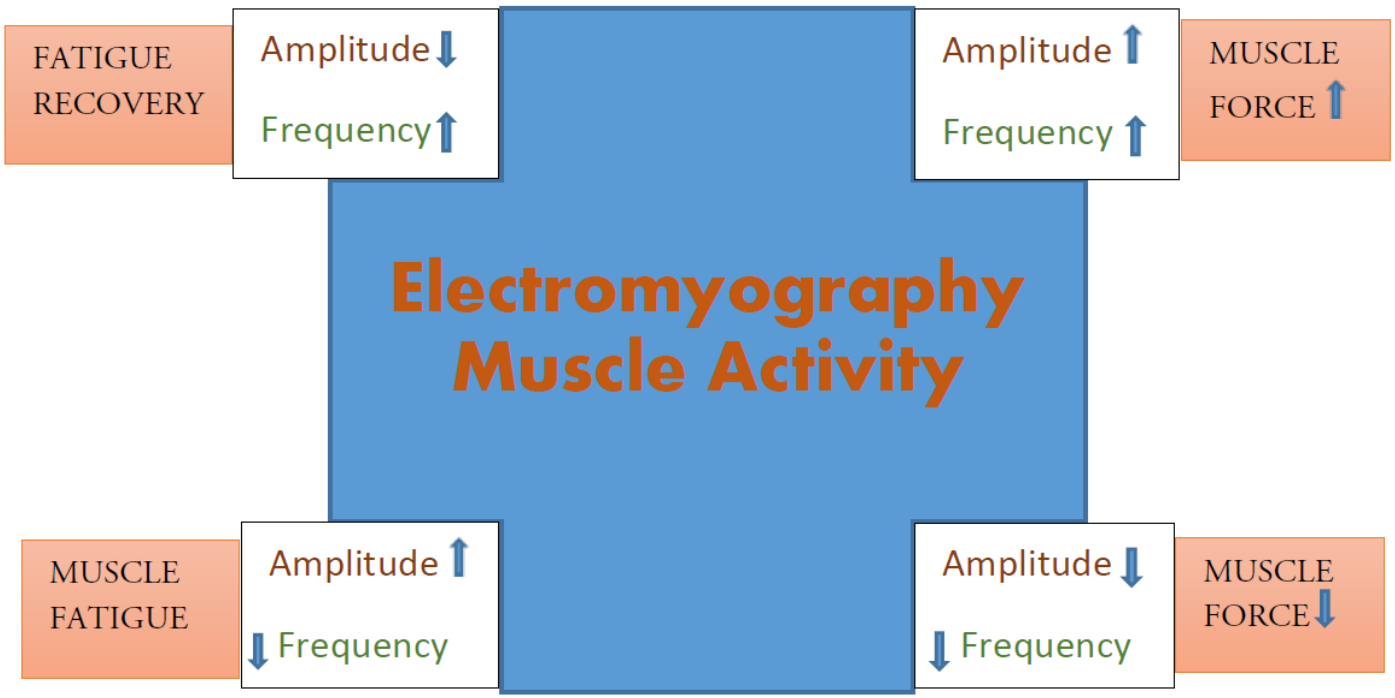
Muscle Force vs Fatigue



Farina et al., 2002 & Cifrek et al., 2009.

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Energy cost in stair machine (lab) Mean (SD) EMG n=23 vs ALL n=25

Parameters	EMG n=23	ALL n=25
Time survived (s)	**255.7 (70.6)**	**259.2 (68.7)**
Max HR (b/min)	**185 (>95% of max HR) (ACSM,.2010)**	**184 (>95% of max HR) (ACSM,.2010)**
Max O2 Uptake (l/min / ml/kg/min)	**3.25 (0.63) / 44.9 (7.3) (>85% VO2max)**	**3.18 (0.65) / 43.9 (7.8) (ACSM,.2010)**
Max met. rate (W/m^2)	**610.5 (85.1)**	**598.6 (91.7) (ISO., 8996)**
Per step (ml/kg/min) and Met. rate (W/m^2).	**0.10 (0.01) and 1.40 (0.35)**	**0.10 (0.04) and 1.38 (0.59)**
VO2 max % reached	**90.87 (5.12)**	**93.59 (6.09)**
HR max % reached	**96.02 (5.85)**	**96.91 (*2.96*)**
Step rate / min	**112.6 (16.8)**	**109.4 (17.9)**
Height reached (m)	**96.8 (10.1)**	**95.02 (30.8)**

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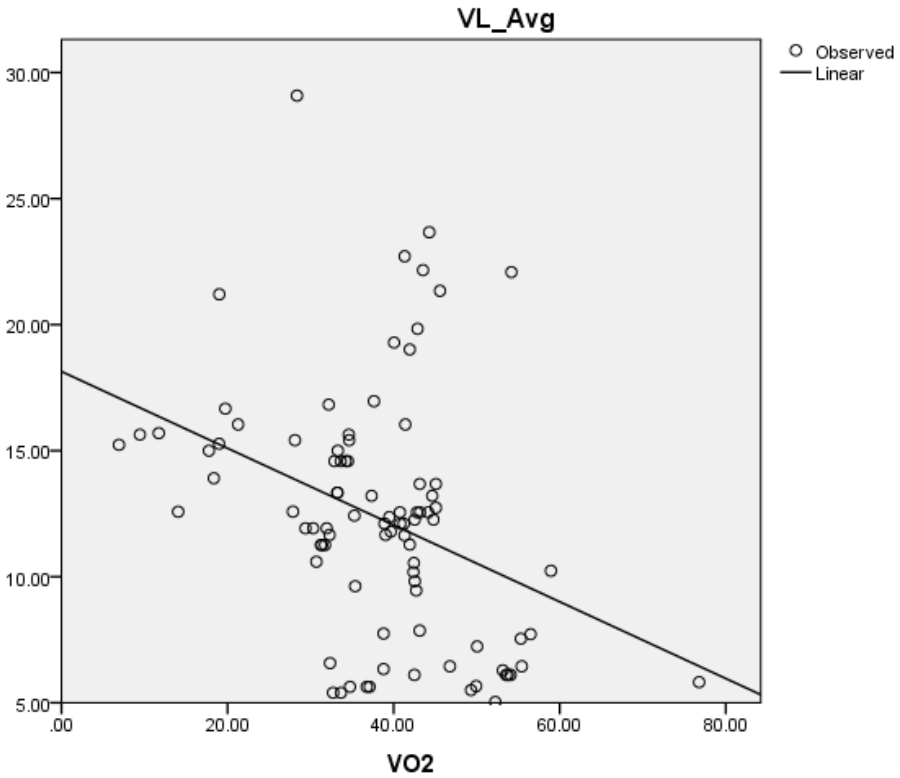
VO2 vs Muscle Amplitude

Model Summary

R	R Square	Adjusted R Square	Std. Error
.357	.128	.118	4.587

The independent variable is VO2.

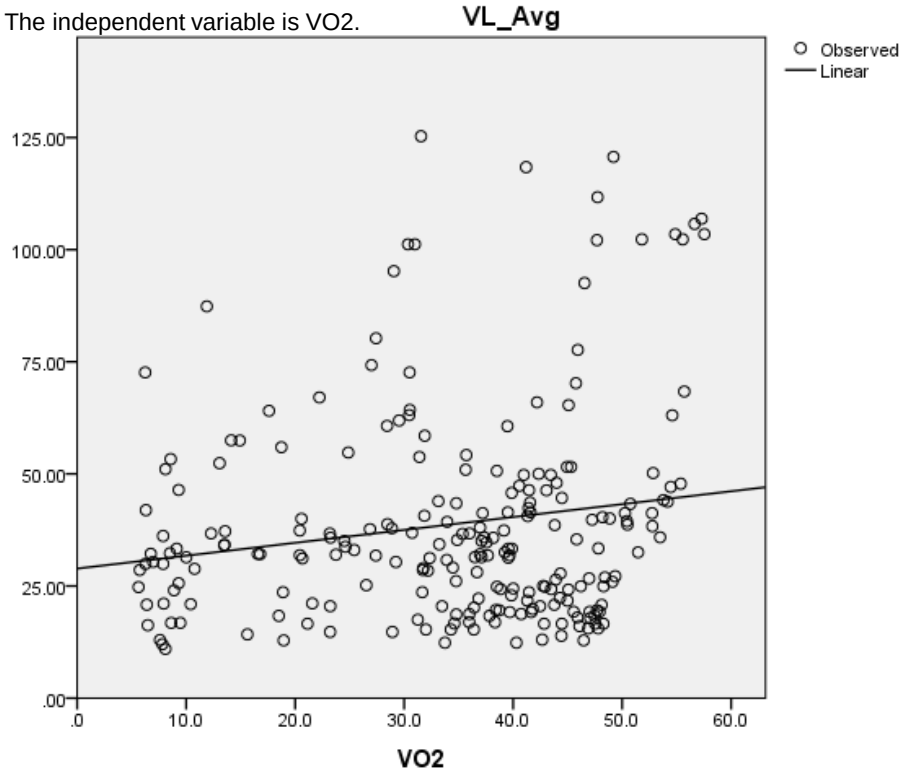


Kista 30-floor
Self-controlled

Model Summary

R	R Square	Adjusted R Square	Std. Error
.170	.029	.025	23.218

The independent variable is VO2.



Laboratory
Study controlled

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Before home message All=102 & EMG=44

Basic comparison	All Subjects				EMG Subjects			
	12Floors n=48	30 Floors n=29	Lab n=25	Average n=102	12 Floors n=12	30 Floors n=9	Lab n=23	Average n=44
Age (Years)	32.5	31.8	35.3	33.2	35.6	33.2	33.5	34.1
Height (m)	1.8	1.7	1.7	1.7	1.7	1.8	1.7	1.7
Weight (Kg)	73.8	70.1	74.4	72.8	72.9	72.5	74.6	73.3
Body Surface Area (m^2)	1.89	1.83	1.86	1.86	1.87	1.86	1.87	1.87
Max HR (b/min)	166	174	185	175	170	177	185	177
Max VO_2 (l/min)	2.8	3.0	3.2	3.0	3.0	3.2	3.3	3.1
Max VO_2 (ml/kg/min)	38.6	41.4	43.9	41.3	40.5	45.0	44.9	43.5
Max Met. rate (W/m^2)	495.0	559.0	598.6	550.9	553.6	601.2	610.5	588.4

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Summary for home message (All=102 & EMG=44)

Speed reduced= Decreased Frequency, Decreased Amplitude and end with Increased Amplitude (Field Studies)- Force ⬇

Speed static= Decreased Frequency, Increased Amplitude (Lab Study)-Muscle fatigue

Max HR: 175> b/min 85% of max HR (ACSM., 2010)

Max VO2: More than 3.0 l/min **OR** 42.0 ml/kg/min (>85% of VO2max) (ACSM., 2010)

Max Met. rate: 550**>**W/m^2 (80-90%) of max work capacity (ISO., 8996).

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Summary
For YOU to HOME

- Stair ascent is a moderate to high intensity task in terms of leg muscle force production and cardiorespiratory capacities which reached about 85-90% of your maximum capacities.

- Ascending may possible around 9-12 min with tolerable amount of physical stress under self-controlled situations.

- Ascending in stairs maximum 5-8 min (in a controlled as fast speed as possible 85-90% of max capacities).

- Stair machine can be used as a method for lower limb musculature fatigue.

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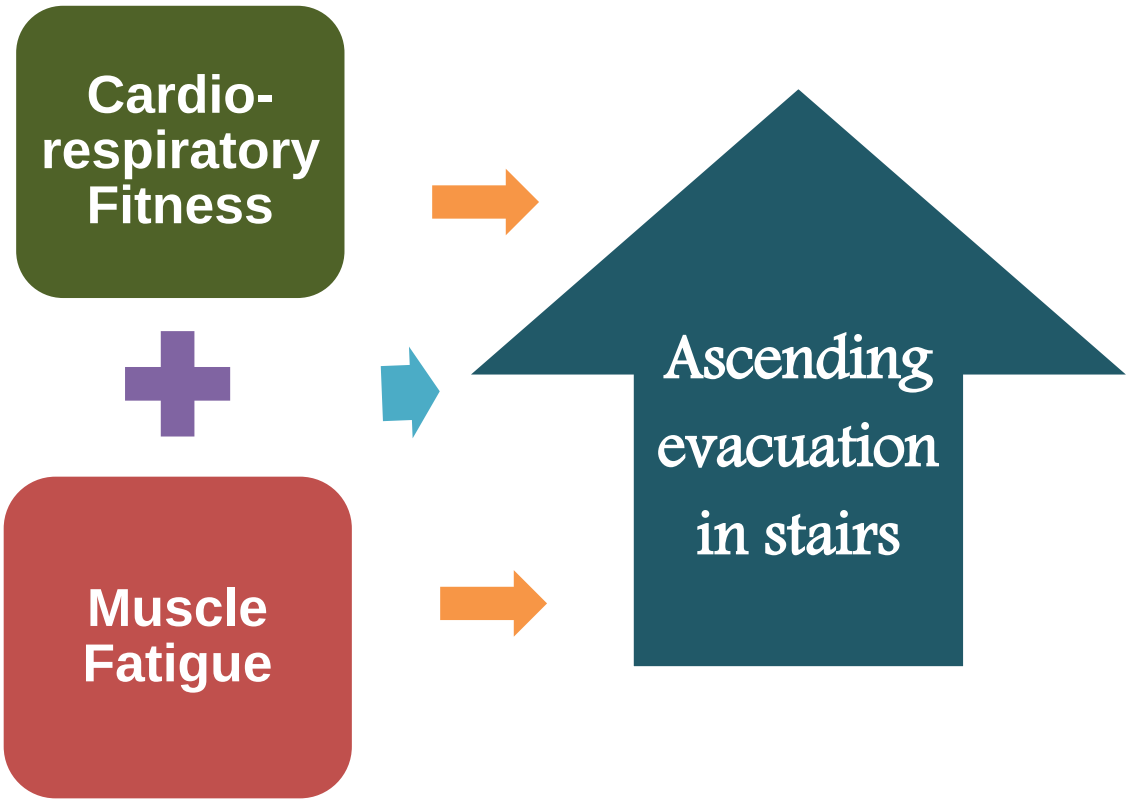
MILLION Thanks



Questions?

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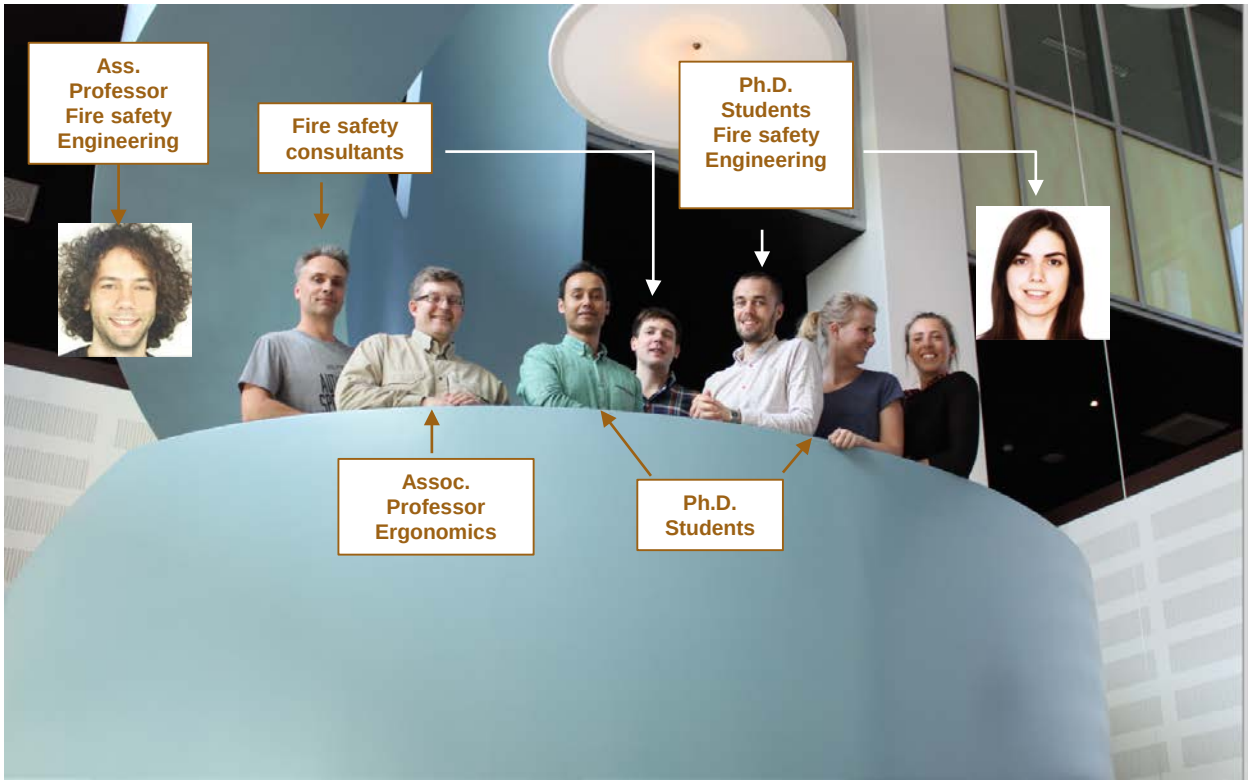
STAIR Climbing: *The Life ENHANCER*

A holistic group and approach

A multidisciplinary project group



Email: amitava.halder@design.lth.se

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Email: amitava.halder@design.lth.se

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