Development of data processing algorithms for portable technologies to measure movement quality and muscle fatigue in Northern populations and workers: a pilot study.

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INTRODUCTION

Muscle fatigue, awkward posture, and repetitive movement could be an important risk factors for the development of musculoskeletal disorders in Northern Populations and Northern Workers. Our general hypothesis is that continuous monitoring during activities of daily living (including at the workplace) with portable technologies to measure movement quality and muscle fatigue would be an effective means to help identify “risky motor behaviors” (e.g. muscle fatigue leading to altered movement coordination), and help the development of online feedback systems to reduce such risks.

Specific objectives: Adapt quantitative laboratory tools to measure the development of **muscle fatigue** and **motor incoordination** by looking at **2 indicators :**

1. A drop in Median Frequency of surface electromyography (EMG);
2. A drop in movement pattern coherence, as means of measuring muscle fatigue/movement quality in real time during actual movement (gait).

METHODS

PROTOCOL: In order to assess the accuracy/sensitivity of measurement, the "indicators" must be tested during standardized tests. Two groups of fifteen healthy subjects volunteered to participate in a one session study.

- Group #1: Overground walking (natural gait speed with inherent variability)
  - (n=15, Gender F/M n=9/6, age 24.6±3.4 yrs., mass 65.5±9.2 Kg, height 173.9±8.9 cm)
- Group #2: Treadmill walking (fixed gait speed)
  - (n=15, Gender F/M n=7/8, age 23.7±3.8 yrs., mass 70.7±14.7 Kg, height 174.8±7.0 cm)

walk test 5-6 min → Fatigue protocol → walk test 5-6 min

FATIGUE PROTOCOL:

Tibialis anterior (TA) muscle.

- Perform dorsiflexion (DF) movements against resistance provided by an elastic tubing until total exhaustion :

INSTRUMENTATION:

- Muscle activation (EMG): Trigno Wireless System (Delsys, Boston, USA)
  - Muscles recorded : Tibialis Anterior (TA), Soleus (SOL), medial Gastrocnemius (MG), Rectus Femoris (RF), Vastus lateralis (VL) and Semitendinosus (ST).
- Movement kinematics : Xsens MVN (Xsens Technologies B.V., Enschede, the Netherlands)
  - Joints recorded: flexion/extension (F/E) movement of both hips and knees, and from DF/PF of both ankles.

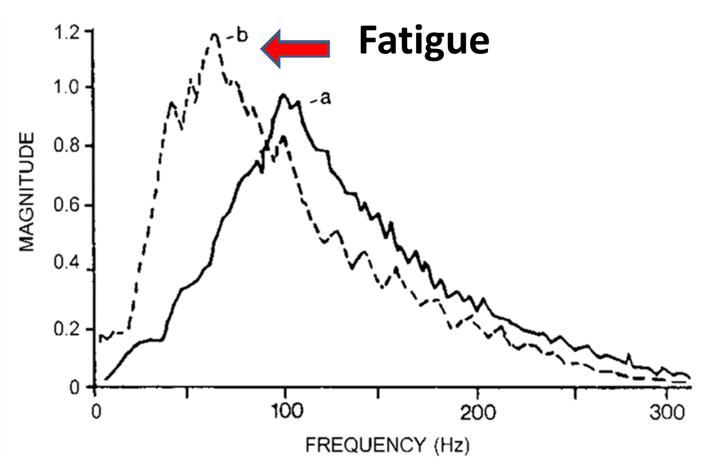
DATA ANALYSIS: All signals were processed using custom software written in MATLAB R2013a (The Math Works Inc., Natick, Massachusetts, United States).

INDICATOR #1: EMG activity in TA muscle

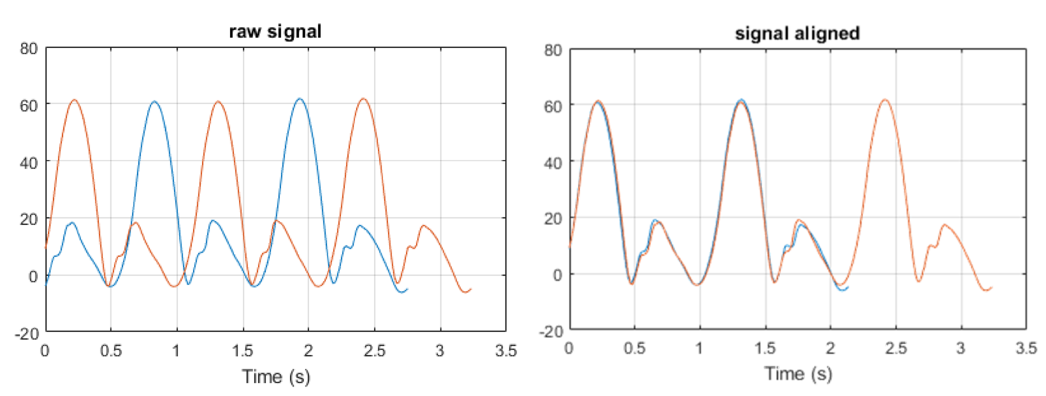
- Digitally filtered off-line with a zero lag 4th order Butterworth filter (band-pass 20–450Hz).
- Median frequency (MF) of the power spectrum was extracted by period of 30s.
- Statistical analysis: MF of the last 30s pre-fatigue walk was compared to the first 30s of the post-fatigue walk using a paired t-test.
- Inter-group differences were compared using unpaired t-tests.

INDICATOR #2: Kinematic of the ankle joint

- Pattern degradation was measured using an algorithm of cross correlation.
- A template was created by averaging 30 to 60 strides of the pre-fatigue walk test and compared to each individual walking cycle.
- Statistical analysis: correlation coefficient of the last 30s pre-fatigue walk was compared to the first 30s post-fatigue walk and to another 30s segment pre-fatigue (serving as a control) using an ANOVA.
- Inter-group differences were then compared using unpaired t-tests.

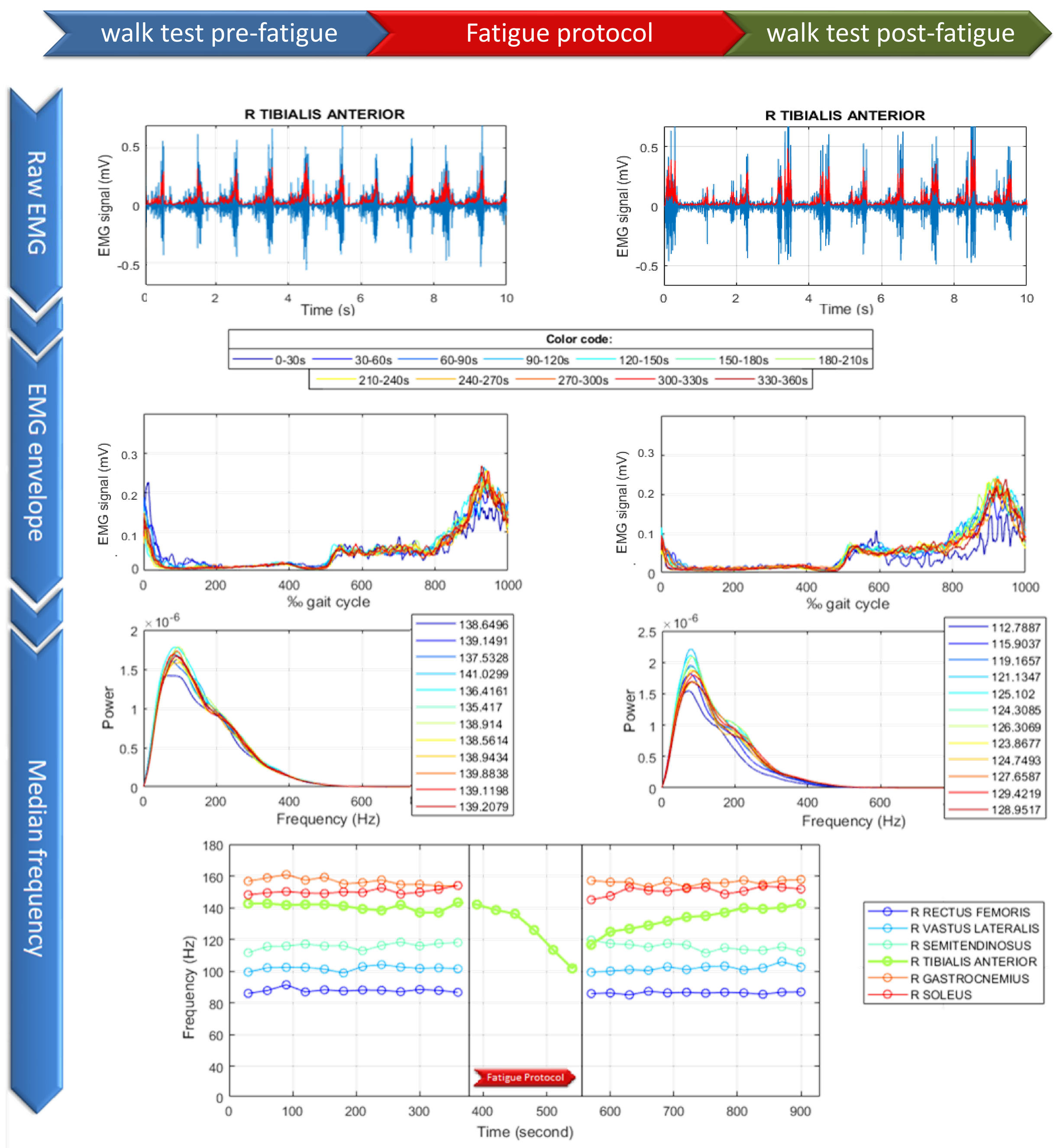


(De Luca, 1984)

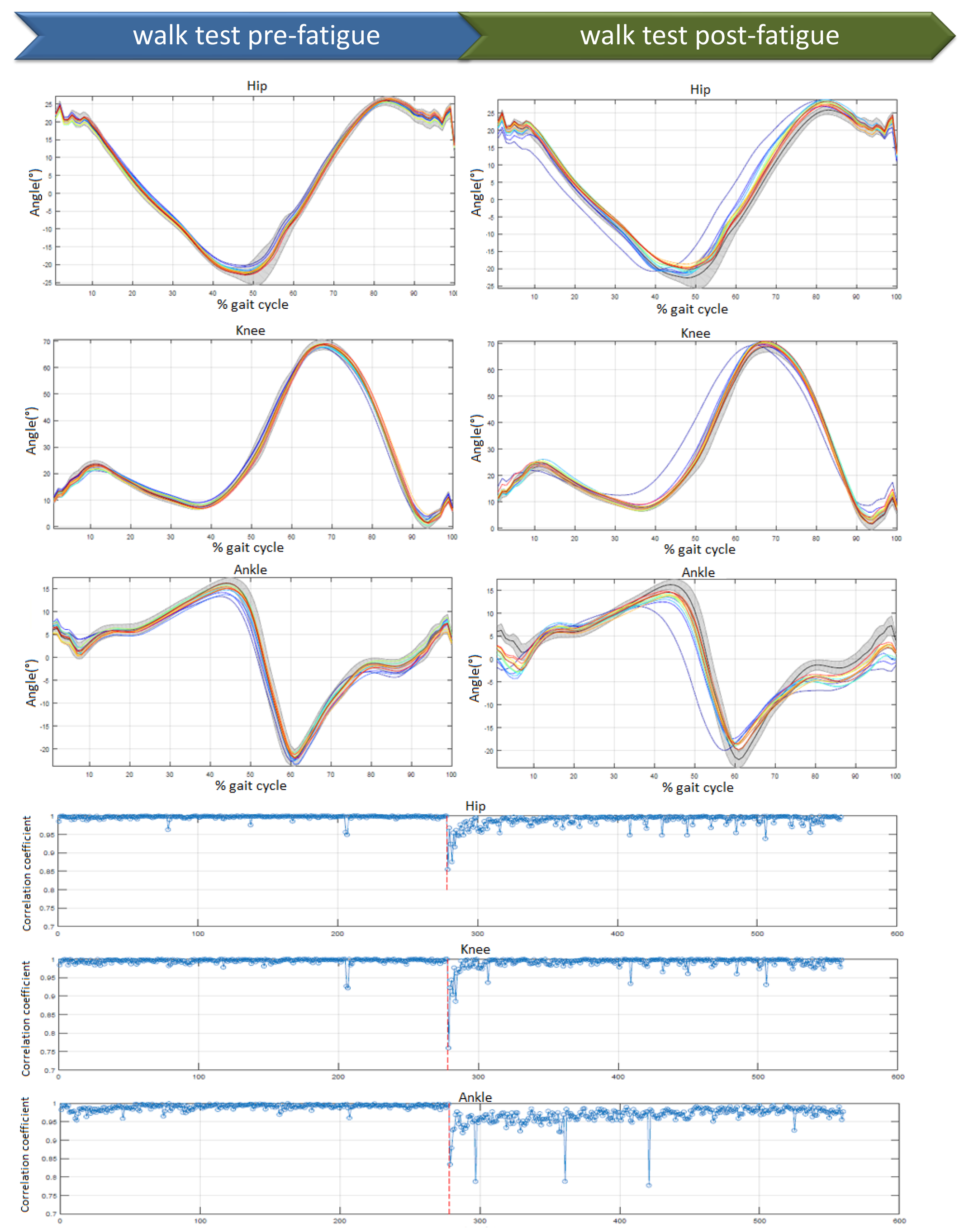


RESULTS

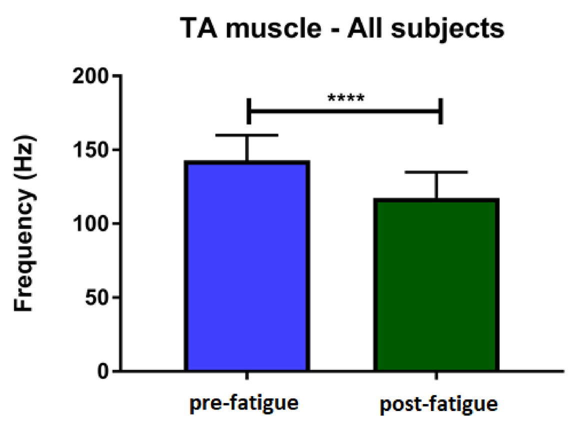
EMG results from a representative subject:

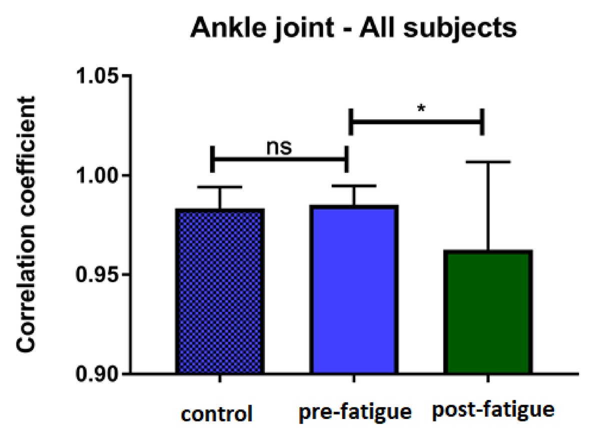


Kinematic results from a representative subject:



Statistical analysis:





RESULTS:

- No statistical difference between treadmill and overground group.
- Shift in the median frequency towards the lower frequencies of the power spectrum of EMG activity in the TA muscle post-fatigue:
  - Decrease of 25,45 ± 8,61 Hz; p<0.0001 post fatigue exercise.
- Significant degradation of the kinematic walking pattern post-fatigue :
  - Cross-correlation reduction of 2,3%; p<0.05 post fatigue exercise.

CONCLUSIONS

- These results confirm that it is possible to rapidly induce muscle fatigue in the TA muscle with a simple experimental protocol.
- Our findings in a ***dynamic task*** are consistent with what is reported in the literature for static evaluations of muscle fatigue[2-5].
- Adaptation of simple laboratory analysis methods, such as EMG median frequency drop and kinematic walking pattern characterization can be an efficient approach for “out of the laboratory” quantitative measurement of muscular effort and changes in movement quality.

ACKNOWLEDGEMENTS

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