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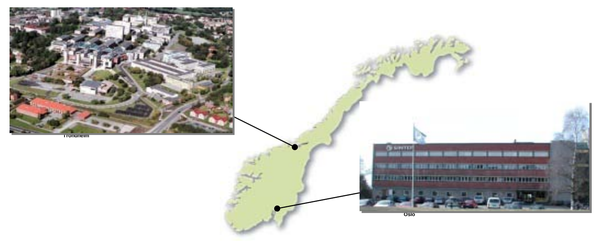

Development of a new sensor fusion algorithm to improve decision support for subjects exposed to heat stress

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Background

The need for decision support

Team leaders for high risk workers must continuously assess the risk for health damage for their team members. Access to real time physiological information is desirable since it can help in the assessment of workers well-being, and ultimately alert when a worker should be withdrawn from their assignment.
This poster describes the development and first tests of a new sensor fusion algorithm, **the Physical and Activity Strain Index (PASI).** PASI combines Physiological Strain Index (PSI) with accelerometer data to improve the decision support for humans exposed to heat stress.

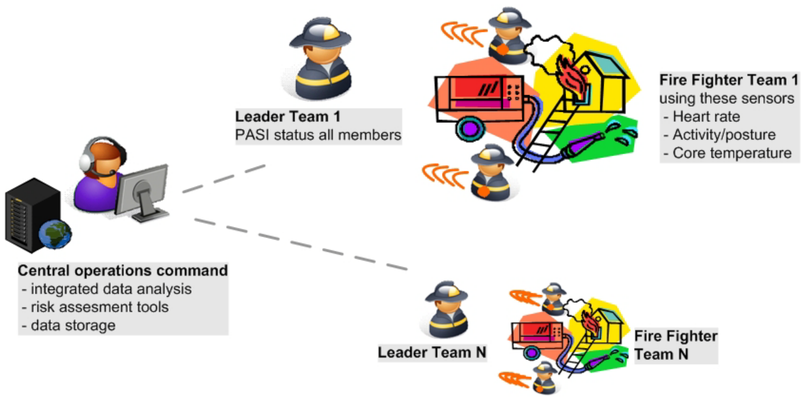

Fig. 1. Decision support system for fire fighters

Heat stress

Heat stress occurs when humidity, air temperature, radiant heat and too little air movement combined with heavy work and clothing to raise the body temperature beyond safe limits. In effect, heat stress reduces the person's physical reactivity and ability to reason clearly.

Examples of groups that are exposed to heat stress :

i) workers wearing protective clothing that provide insulation that prevents evaporation heat loss (Fire fighters, pilots etc)
ii) workers and athletes performing in warm climate

Physical Strain Index (PSI)

The Physical Strain Index developed by Moran [1] is a well accepted index used for monitoring humans working with heat stress.

$$PSI = 5 \cdot \frac{(T_{ret} - T_{re0})}{(39.5 - T_{re0})} + 5 \cdot \frac{(HR_t - HR_0)}{(180 - HR_0)}$$

- T_{ret} = core temperature
- HR = heart rate

PSI results in a number between 0 and 10 (if 36.5°C <= CT <= 39.5°C and 60bpm <= HR <= 180bpm), with 10 as the highest risk.

Tab 1. Correlation between evaluation of strain and PSI index.

Strain	PSI
No/Little	0-2
Low	2-4
Moderate	4-6
High	6-8
Very High	8-10

[1] Moran, D.S., Shitzer, A. and Pandolf, K.B., A physiological strain index to evaluate heat stress, Am J Physiol Regulatory Integrative Comp Physiol., 1998, 275:129-134

PASI- Physical and Activity Strain Index

Combining PSI with the Activity Index

The Physical and Activity Strain Index has been developed to improve decision support for workers exposed to heat stress. Fire-fighters (smoke divers) has been used as test case.

PASI consists of two parts, the PSI and an Activity Index (AI). As for PSI the output of the algorithm will be a number between 0-10 (for 36.5°C <= CT <= 39.5°C and 60bpm <= HR <= 180bpm).

PASI = PSI + AI,
where AI_{MAX} = 10-PSI

PASI combines the PSI and the AI, so that when the PSI increases, the toleration for the AI will decrease and vice versa. This has been illustrated in Fig.2.

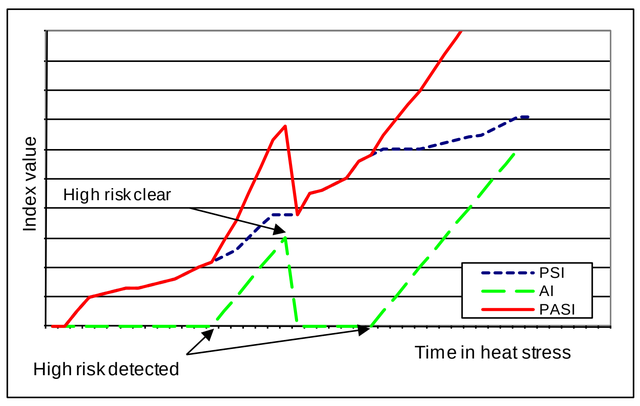

Fig. 2. Graphic illustration of Physical and Activity Strain Index (PASI), Activity Index (AI) and Physical Strain Index (PSI).

High risk situations that PASI reveals

- Fire-fighter is lying still on the floor with normal heart rate and core temperature
- Fire-fighter has had a fall
- No movement for a "long" time
- Panicky movements
- High speed
- Repeated stumbling / almost falling

Low risk situations that PASI ignores

- Walking around
- Running for short time
- Standing still for a while
- Crawling

Test environment and equipment

The PASI algorithm has been tested in the lab at SINTEF ICT using sensor systems that are commercially available for physiological monitoring in the market today; Hidalgo Equivital and Zephyr BioHarness. The subjects wore smoke divers' equipment including simulated load from the oxygen container.

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Test results

The graphs below show how heart rate, temperature (Fig. 3), PSI (Fig. 4), AI (Fig. 5) and PASI (Fig. 6) change with time as the test person is subject to different levels of activity stress on the treadmill. Test subject 2 simulated two fall incidents.

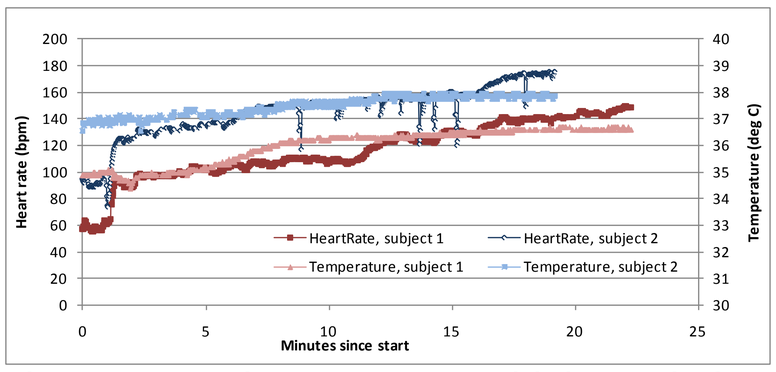

Fig. 3. Heart rate and temperature measured during exercise for two subjects.

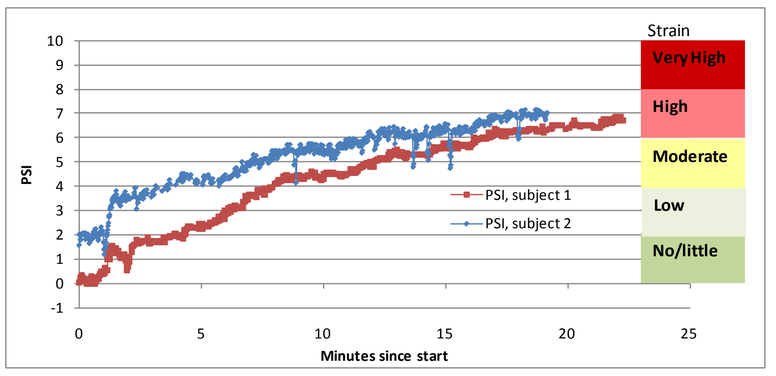

Fig. 4. Physical and Activity Strain Index (PASI) derived from data shown in Fig. 3 (two subjects) .

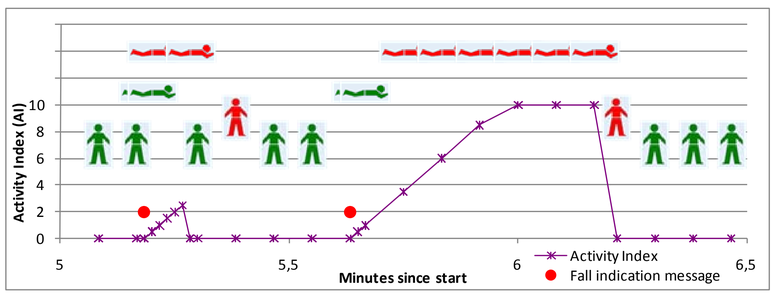

Fig. 5. Activity Index (AI) during fall situations for test subject 2. AI is derived from the received posture and motion messages from the accelerometer. (Red man indicate inactivity, green man activity)

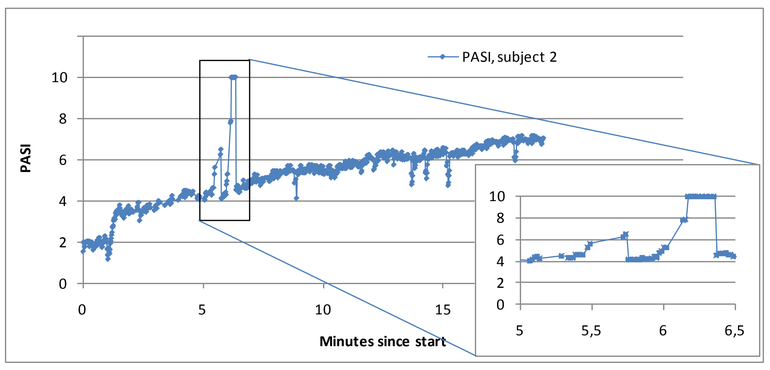

Fig. 6. Physical and Activity Strain Index (PASI) derived from data shown in Fig. 4 and Fig.5 for test subject 2.

Conclusion

The first lab testing indicates that it is possible to distinguish several high and low risk situations with data from accelerometers. Therefore, PASI can contribute to an improved risk assessment and decision support for fire fighters in action compared to using PSI alone.

This can be used for early detection of health risks for workers in high strain situations and for more effective use of personnel resources.

Acknowledgment

We thank Mosseregionens interkommunale Brann og Feiervesen, Norway, for lending the fire fighter equipment for laboratory testing, and for valuable input about firefighters work.