CLINICAL APPLICATIONS OF A MAGNETIC SENSOR MEASURING DISTANCE ON THE HUMAN BODY

Nomics, Liège Science Park (BELGIUM)

INTRODUCTION: Direct observation of patients experiencing sleep-disordered breathing (SDB) hinted that breathing efforts were accompanied by characteristic movements of the mandible. Therefore, measuring and analyzing jaw movements during sleep could constitute a powerful solution to overcome the limitations of commonly used methods of measuring respiratory efforts. To this end, a simple, non-invasive magnetic-based motion sensor was developped. After the sensor demonstrated its usefulness in the diagnosis of SDB, other clinical applications emerged: the sensor could also be useful in radiotherapy and in applied physiology.

TECHNOLOGY: The sensor is composed of two coils forming two circuits with matching resonant frequencies. Pulses of excitation energy are delivered to the transmitter coil, inducing a magnetic wave that travels and excites the receiver coil. The magnitude of the signal generated at the receiver coil depends, all other conditions being equal, on the distance between the coils (figure 1 - LEFT). Therefore that distance can be calculated from the properties of the received signal, using a patented signal processing technique.

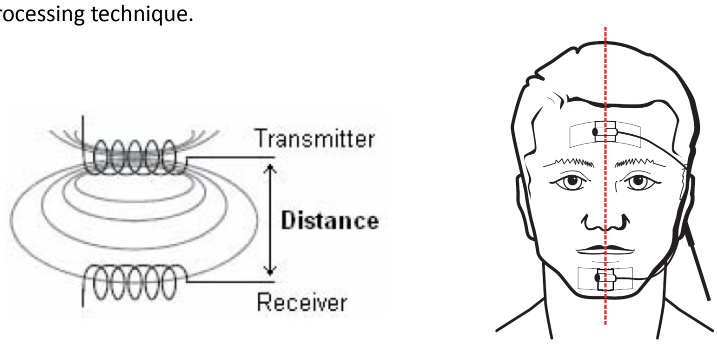


Figure 1:
LEFT - Principle of the magnetic distance sensor.
RIGHT - Attachment of the sensor to measure jaw movements, via the measurement of the distance between the two elements of the sensor, one taped on the forehead and the other one on the chin.

The magnetic pulses generated by the sensor are of very low energy and of very short duration. Therefore the sensor can be used safely to measure distances on the human body. Note that, in order to obtain an accurate measure of distance between them, the two coils must be parallel and on the same axis (figure 1 – RIGHT). The 0.1mm resolution achieved by the system allows it to detect and measure very fine movements.

CLINICAL APPLICATIONS – SLEEP MEDICINE: Sleep-disordered breathing may have severe consequences like hypertension, heart disease, and fatigue related accidents. Yet it is still widely underdiagnosed among adults and children. Although polysomnography (PSG) in a sleep lab provides the most detailed evaluation of sleep disturbances, it is costly, time-consuming and not largely available. The need for at-home preliminary screening with ambulatory devices is well recognized by clinicians.

Respiratory effort is an essential parameter to be measured in order to differentiate subsets of sleep related breathing disorders and to select appropriate treatment. However, common methods of measuring respiratory effort are impractical for at-home sleep monitoring. For example, while oesophageal pressure monitoring is the gold standard for assessment of breathing efforts, it is too invasive and cumbersome to be used outside of the laboratory.

The magnetic distance sensor described above offers a convenient alternative method of respiratory effort measurement. In this application, the magnetic distance sensor measures jaw movements (Figure 1 – RIGHT). Indeed, the mandible is subject to some specific behaviors during abnormal breathing events [1]. An automatic analysis algorithm was created in order to diagnose obstructive sleep apnea (OSA) from the recording of mandibular movements. A comparative study showed that the Apnea-Hypopnea Index (AHI) computed from mandibular movements by this automatic method was accurate, reliable and in correlation with the AHI computed from oesophageal pressure measurement [2]. Therefore, the recording and automatic analysis of jaw movements during sleep constitutes a good surrogate for oesophageal pressure monitoring and offers a non-invasive and user-friendly method for the screening of OSA.

nomics • Rue des Chasseurs Ardennais 4 • B-4031 Angleur • BELGIUM
Tel : +32 (0)4 372 93 48 • email : sales@nomics.be
www.somnolter.com

CLINICAL APPLICATIONS – RADIOTHERAPY: In radiation therapy, accurate knowledge of the localization and shape of a tumor is essential in order to destroy it while sparing healthy surrounding tissue. As a number of organs are subject to respiratory motion, tumors located in these areas move too. Therefore, some equipment is needed in order to either directly monitor the position of the tumor during beam delivery or indirectly localize the tumor by correlating tumor motion with that of a respiratory marker.

When applied to the chest or abdominal wall, the magnetic distance sensor described above constitutes such a respiratory marker and assists clinicians in studying and monitoring patient respiration during radiotherapy [3].

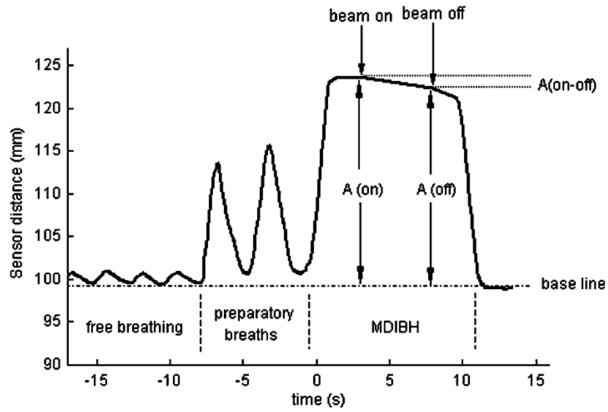
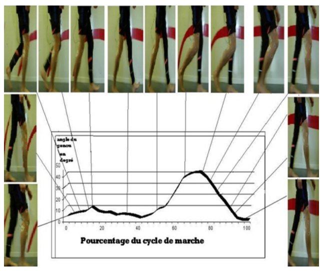


Figure 2: Typical breathing curve monitored by magnetic distance sensor during moderate deep inspiration breath hold (MDIBH) treatment; A(on) is the amplitude when the beam is switched on; A(off) is the amplitude when the beam is switched off.

CLINICAL APPLICATIONS – APPLIED PHYSIOLOGY: Gait analysis is another domain where the magnetic distance sensor can be useful. For example, it was demonstrated that by taping the sensor on the leg, each element at equal distance of the knee joint, one obtains a distance signal which evolves in perfect agreement with the knee angle signal extracted from video data.



This opens up the possibility of recording gait over long periods of time, on long distances, and in environments where introducing a video acquisition system is impracticable.

In applied physiology, the use of the magnetic distance sensor as a tool to estimate ventilation and energy expenditure has also been investigated. In this application, two pairs of electromagnetic coils allow to measure rib cage, abdominal and chest wall distances (Figure 3). From these measurements, it was possible to accurately estimate ventilation and energy expenditure, in sitting, standing, and moderate exercise conditions [4] [5]. This research sets up the basis for further investigation of the applicability of the technique to daily life conditions and vigorous physical activity.

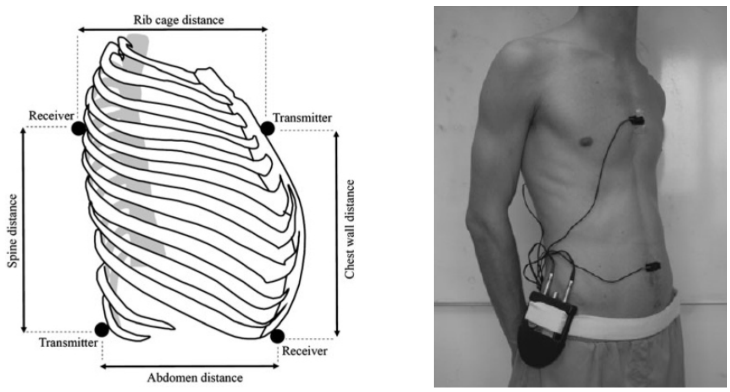


Figure 3: Configuration and placement of the two pairs of electromagnetic coils on the subject

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[3] The use of magnetic sensors to monitor moderate deep inspiration breath hold during breast irradiation with dynamic MLC compensators, *Remouchamps et al.*, Radiotherapy and Oncology 2007;82:341–348.
[4] Estimates of ventilation from measurements of rib cage and abdominal distances: a portable device, *Gastinger et al.*, Eur J Appl Physiol 2010;109:1179–1189.
[5] A new method to estimate energy expenditure from abdominal and rib cage distances, *Gastinger et al.*, Eur J Appl Physiol 2011;DOI 10.1007/s00421-011-1900-9.