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Clinical application of wearable strain sensor on respiratory measurement in healthy participants and individuals with breathing problems

保健医療学専攻・理学療法学分野・応用理学療法学領域

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[研究の背景と目的]

Nowadays 92 million patients with various respiratory diseases every year in china, but Diagnosis rate is less than 35%. Spinal cord injury, Brain stem hemorrhage and TBI with respiratory disorders, they all are target patients of respiratory measurement because of high mortality and disability. Respiration movement is an important component in the assessment of pulmonary function. In clinical practice, respiration movement is generally assessed by inspection and palpation in the physical examination, which not only provides real-time observation but does not require any other special measuring devices. Nevertheless, physical examinations are not quantitative, but qualitative analysis based on the experience of an examiner. Although there is gold standard of pulmonary functional test (e.g. spirometer) in clinical application. However, because of long waiting time, limitation of moving conditions, cognitive disorder and etc., many patients did not finish the examinations timely.

Measurement of chest expansion is also a simple and practical method for assessing patients' respiratory function in clinical application. However, measuring devices of chest expansion were both 3-dimensional motion analyzer and a spherical reflective marker, which were required to conduct in a special experimental environment. It is inconvenient for patients in a clinical setting. So various sensors on respiration monitoring were developed, but they still have some limitations. Therefore, a more convenient wearable strain sensor (WSS) was developed for easier to use and more objective measurement of chest expansion in a clinical application without the above-mentioned limitations.

There are four purposes in this research: 1) To confirm the test-retest reliability coefficients and the validity of WSS on measuring respiration movement in healthy male participants; 2) To compare the correlation between WSS and spirometer on measuring respiration movement in healthy male participants, then to find the best body spot (10th rib) to detect the positive significant correlation on the chest -abdomen wall; 3) To explore change of breathing pattern by aging using WSS among different age groups; 4) To assess changes of chest-abdomen wall after respiratory exercise in individuals with cervical spinal cord injury using WSS.

[研究方法および結果]

【研究 1】 The reliability and validity of measuring respiration movement using WSS

- 1) **Subjects:** The characteristics of all healthy male students in this study. (n=21)
- 2) **Instruments:** A wearable strain sensor (WSS) and measuring tape (MT)
- 3) **Methods:** Using WSS and MT respectively, to measure the different degree of chest expansion from maximal end of expiration to maximal end of inspiration at four places (Axilla, xiphoid process, 10th rib, and umbilicus)
- 4) **Data analysis:** The intra-rater ICC (1,1) with 95% confidence interval and Pearson's correlation analysis.
- 5) **Results:** All ICC values for intra-rater reliability were higher at all places, which means that there is a high correlation. All values for validity showed significantly positive, indicating that there is a correlation between the WSS and MT at four places.

【研究 2】 The best body spot to detect the vital capacity from the respiratory movement data obtained by WSS

1) **Subjects:** All male participants baseline characteristics (n=30)

2) **Instruments:** WSS and spirometer

3) **Methods:** Using WSS at four spots (Axilla, xiphoid process, 10th rib, and Umbilicus) on chest and abdomen wall and spirometer respectively, to measure from maximal end of inspiration to maximal end of expiration.

4) **Data analysis:** Pearson's correlation analysis.

5) **Results:** Correlation r-value at 10th rib is 0.824. So, the 10th rib is the best body spot to detect the positive significant correlation.

**【研究 3】 Application of using WSS on respiratory evaluation in physiotherapy-----
changing with aging in breathing pattern**

1) **Subjects:** The baseline characteristics of all male participants (n=82)

2) **Instrument:** WSS

3) **Methods:** Using WSS to measure at four torso spots (Axilla, xiphoid process, 10th rib, and Umbilicus) on chest and abdomen wall from maximal end of inspiration to maximal end of expiration.

4) **Data analysis:** Two-way ANOVA to compare among three groups, then the Bonferroni as a post-hoc test to ascertain the significant differences.

5) **Results:** There are significant differences at three spots among three groups, only at umbilicus, there is no significant difference between middle-age group and senior group ($p>0.05$). It is no meaning to measure the expansion range at umbilicus for senior people.

【研究 4】 Measuring changes of chest-abdomen wall in individuals with cervical spinal cord injury (CSCI) using WSS

1) **Subjects:** The baseline characteristics of all male individuals with CSCI (n=93)

2) **Instrument:** WSS

3) **Methods:** Using WSS to measure at four torso spots (Axilla, xiphoid process, 10th rib, and Umbilicus) on chest and abdomen wall from maximal end of inspiration to maximal end of expiration.

4) **Data analysis:** Two-way ANOVA was used for the analysis differences between experimental group (EG) and control group (CG), then the Bonferroni as a post-hoc test to ascertain the significant differences.

5) **Results:** The result of the data analysis shows that that the expansion of the chest wall (axilla, xiphoid process) after exercises for the end of one month in EG was obviously more than that after the exercises for the end of one week ($p<0.05$), while the abdomen wall expansion maintained no differences ($p>0.05$).

【結語】

It is considered that WSS may replace the physical examination as an objective measurement for respiratory movement in clinical application, because this study presented that WSS has been proved to have a high degree of reliability and validity, providing scientific and valuable evidence, and without limitation of posture or environment during respiration measurement.

【倫理上の配慮】

The Ethic Committees of International University of Health and Welfare (No.16-Io-176, No.16-Io-177, No.16-Io-237, No.16-Io-238) and China Rehabilitation Research Center (CRRC-IEC-RF-SC-005-01) approved the study protocol.

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