Comparison of Neck Movement Smoothness between Clients with Mechanical Neck Disorder and Asymptomatic Individuals Using Spectrum Entropy Method

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SUMMARY
Mechanical neck disorder (MND) constitutes one of the most common health issues of the modern lifestyle. Improving knowledge of the complicated neck kinematics of would overcome the problem. Therefore, the objective of this work is utilizing the power spectrum entropy of acceleration time-series and another important index about the smoothness and efficiency of a movement in the clinical setting, the number of movement units, respectively to compare the characteristics of neck movement smoothness in clients with MND with asymptomatic individuals. A total of thirty subjects (MND: n=19, Asymptomatic: n=11) participated in this study. Using electromagnetic tracking system collected the kinematic data of neck circumduction. The results showed clients with MND had higher value in the spectral entropy of acceleration time-series ($p=0.047$) and the number of movement units ($p=0.018$) than asymptomatic individuals. Moreover, a significant positive correlation was found between the spectral entropy of acceleration time-series and the number of movement units for all the participants ($r=0.722$, $P<0.01$). Accordingly, the findings concluded a significantly less smooth cervical movement in clients with MND.

INTRODUCTION
Mechanical neck disorder (MND) constitutes one of the most common health issues of the modern lifestyle and exhibits restricted cervical range of motion, neck muscle weakness and neck-related functional disabilities. Additionally, the concept of movement smoothness is getting more attention gradually for the coordination of the human joint. Often, the jerk index defined as the time derivative of acceleration has been used to quantify the movement smoothness [1]. Since the jerk index is a speed-dependent measure, it would be not suitable to assess the self-paced movements. On the other hand, there are increasing evidences indicating the power spectrum entropy is an effective approach to analyze the occurrence probability of a signal and further serves as an indicator for the irregularity or smoothness of human locomotion [2]. However, no related studies apply the spectrum entropy to explore the neck movement smoothness for clients with MND. Thus, the objective of this work is utilizing the power spectrum entropy of acceleration time-series to compare the characteristics of neck movement smoothness in clients with

MND with asymptomatic individuals. Also, the number of movement units, which is another important index about the smoothness and efficiency of a movement in clinical setting and defined as one acceleration phase and deceleration phase in a velocity profile [3], is conducted to compare the results from the power spectrum entropy of acceleration time-series.

METHODS
In total, thirty subjects participated in this observation. Eleven of these subjects were asymptomatic individuals. None of the subjects had any history of cervical problem. Besides, the remaining nineteen subjects were enrolled in the MND group while they had received their diagnoses by a physician and had sought medical treatment within the past six weeks. Prior to the study, all subjects gave informed consent to the experimental procedures.

In order to obtain three-dimensional neck kinematics, the neck circumduction which is composed of all the neck movements of the three major anatomical planes was executed. A six degrees-of-freedom electromagnetic tracking system (LIBERTY[TM], Polhemus Inc, USA) at a measurement frequency of 120 Hz was chosen for recording the kinematic data. In the present investigation, two sensors placed on the vertex of the head and over the processus spinosus of the seventh cervical spine body respectively were adopted to collect the acceleration time-series for the neck circumduction. The raw kinematic data were smoothed using a low-pass second-order Butterworth filter with a 6-Hz cutoff frequency and the smoothed kinematic data were converted into frequency spectrum by using a fast fourier transform. Then, the power spectral entropy of acceleration time-series was determined by the following formula[3]:

$$\text{Stectral entropy} = \frac{-1}{\log_{10} M} \sum_{i=1}^{n} [\text{PSD}_i \times \log_{10}(\text{PSD}_i)]$$

where PSD_i was the normalized value of the power spectrum density of acceleration time-series at the ith frequency bin and M denoted the number of frequency bins. The higher spectral entropy represents less smoothness of the movement, whereas low spectral entropy implies smoother movement. For the number of movement units, it was determined by calculating the number of the occurrences of acceleration and adjustment deceleration in a velocity

profile [3]. The increase in the number of movement units indicates a decline in the smoothness of movement. Finally, the non-parametric Mann-Whitney U-test was conducted to determine whether there were differences in kinematic variables between clients with MND and asymptomatic individuals, and also the Spearman's correlation was applied to clarify the relationship between the spectral entropy of acceleration time-series and the number of movement units. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS 12.0, Chicago, IL). A significance level of $p < 0.05$ was used in all analyses.

RESULTS AND DISCUSSION

Table 1 outlines the demographic data and the characteristics of neck movement smoothness for asymptomatic individuals and clients with MND. In addition, Figure 1 illustrates the distribution for the normalized value of the power spectrum density of acceleration time-series for the neck circumduction from an asymptomatic individual and one client with MND. The current study suggested the clients with MND on average showed higher value in the spectral entropy of acceleration time-series ($p=0.047$) and the number of movement units ($p=0.018$) than asymptomatic group. Simultaneously, higher and more dispersive components of frequency spectrum appeared in clients with MND compared with asymptomatic individuals. Moreover, clients with MND also exhibited more number of movement units. Thus, the observation confirmed a significantly less smooth neck movement in clients with MND. One potential reason contributing to the phenomenon could be the clients with MND altered neuromuscular control strategies, such as increased degree of co-activation of muscle in neck region to avoid the occurrences of neck muscular strain and painful movements [4].
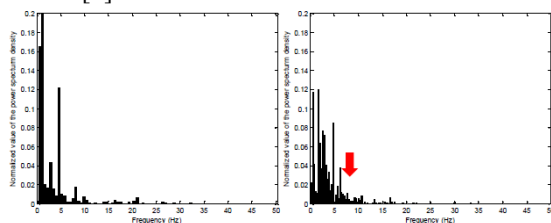

Figure 1: Distribution for the normalized value of the power spectrum density of acceleration time-series for the neck circumduction from an asymptomatic individual (A) and one client with MND (B).

Finally, the scatter diagram of the spectral entropy of acceleration time-series versus the number of movement units for all the subjects is presented in Figure. 2. Undoubtedly, a statistically significant positive correlation was found between the spectral entropy of acceleration time-series and the number of movement units for all the participants ($r=0.722$, $P<0.01$). That is, the findings implied the subject who performed more numbers of movement units would lead to less smooth cervical movement and reduce the coordination of the cervical movement.
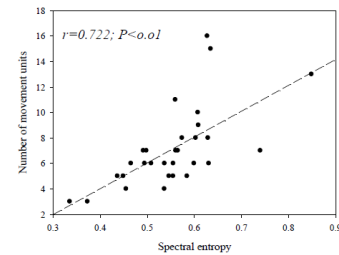

Figure 1: Scatter diagram of the spectral entropy of acceleration time-series versus the number of movement units.

In summary, the current study substantiated different motor control strategies between clients with MND and asymptomatic individuals, indicating a significantly less smooth neck movement in clients with MND. Moreover, the findings concluded the subject who performed more numbers of movement units would reduce the neck movement smoothness. However, the sample size recruited in this observation was still small. The results might not exactly reflect the symptomatic phenomenon for the general populations. Further work will be to increase the sample size to strengthen our findings. This manner could improve knowledge of the complicated neck kinematics between the clients with MND and asymptomatic individuals.

CONCLUSIONS

It is concluded the power spectrum entropy of acceleration time-series would be a useful approach to quantify the neck movement smoothness. Also, the findings verified the notion that different motor control strategies were exhibited between clients with MND patients and asymptomatic individuals.

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Table 1: Demographic data and characteristics of the smoothness of cervical movement for healthy and MND subjects.

	Healthy subjects (7 males and 4 females)	MND patients (10 males and 9 females)	*P*-value
Age (years)	25.09 (4.35)	25.58 (4.56)	
Height (cm)	168.00 (8.34)	165.53 (8.75)	
Weight (kg)	63.36 (13.45)	59.68 (9.53)	
Neck disability index		19.83 (5.29)[a]	
Spectral entropy	0.51 (0.08)	0.58 (0.10)	0.047*
Number of movement units	5.45 (1.51)	8.11 (3.45)	0.018*

* A significant level at 0.05.
[a] Twelve of nineteen subjects with MND (7 men, 5 women) completed the Neck Disability Index.