Towards Quantifying Movements in Qigong

Melanie Baldinger[1], Patrick Carqueville[1], Thomas Geier[1], Christian Schuster[1], Jiexiang Shu[1], Aljoscha Hermann[1] and Veit Senner[1]
[1] Technical University of Munich, School of Engineering and Design, Professorship of Sport Equipment and Materials, Boltzmannstr. 15, Garching, 80574, Germany

Introduction: Qigong is a method of physical activity that is characterized by practicing the connection of body, mind and breathing [1]. In this pilot study, we analyze the movement sequence *Pushing the wave* in terms of synchronicity and smoothness as indicators of movement quality. The goal is to identify parameters to generate meaningful feedback for learners using wearable sensors.

Method: A total of 20 beginners with no prior experience in Qigong and one professional Qigong master participated in the study. Each subject was equipped with an inertial measurement unit (BNO085, Adafruit, New York City, USA; sampling rate 200 Hz) on each wrist. Additionally we attached piezo-resistive silicone filaments [2] around the torso to measure breathing using the change of electrical resistance (at 200 Hz). All participants signed a written and informed consent and the experiment was in line with the Declaration of Helsinki. Participants were instructed to perform 8 cycles of the exercise *Pushing the wave* (see Fig. 1). All recordings were post-processed in Matlab R2021a. Outliers were removed and the data were smoothed using the Savitzky-Golay filter (smoothing factor 0.25). The sequencing of the individual cycles was carried out using the turning points in the acceleration curves. The following four parameters were evaluated in the data analysis: (1) *Synchrony of movement and breathing*: We compared the time of the change of movement direction close to the body (acceleration maxima) with the onset of exhalation (breathing curve maxima) and the time of the change of movement direction far from the body (acceleration minima) with the onset of inhalation (breathing curve minima). (2) *Repeatability of cycle duration* was assessed comparing the individual cycle durations. (3) *Movement of left and right hand* was compared for the time of the change of movement direction far from the body. (4) *Amplitudes of acceleration* of the average of both hands were compared across all cycles.

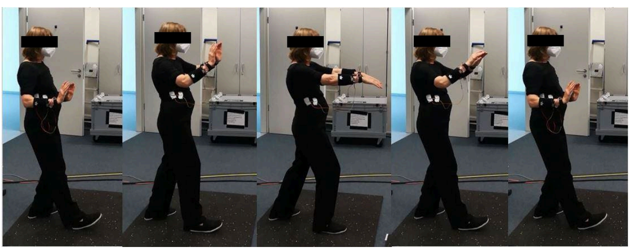

Fig. 1: *Pushing the wave*: After inhalation both hands are pushed evenly forward from the center of the body synchronously with the exhalation until the arms are fully extended. The inhalation begins and the hands are slowly moved back to the center of the body.

Corresponding author email: melanie.baldinger@tum.de

Results: For each of the four analyzed parameters the results of the master and the beginners are summarized in Table 1.

Table 1: Results of the master and the beginners over all cycles (mean ± standard deviation).

Parameter		Master (n = 1)	Beginners (n = 20)
Synchrony of movement and breathing	Δ movement turning point and breathing alteration	2.79 ± 0.68 s	1.02 ± 0.94 s
Repeatability of cycle duration	cycle duration	11.21 ± 0.47 s	5.63 ± 0.37 s
Movement of left and right hand	Δ turning point of left and right hand	0.16 ± 0.15 s	0.21 ± 0.19 s
Amplitudes of acceleration	average acceleration of both hands	max = 0.28 ± 0.04 m/s^2 min = -0.24 ± 0.03 m/s^2	max = 0.83 ± 0.14 m/s^2 min = -0.85 ± 0.12 m/s^2

Discussion: The master achieved lower variability in all parameters except for cycle duration. This indicates a smooth exercise execution, which is favorable in terms of movement quality. However, in terms of synchrony of movement and breathing beginners showed less variation. This could be due to special focus on breathing which obviously is not the case for the master. She seems to practice a more relaxed and natural breathing rhythm, which comes at the expense of synchronicity. Thus, an intelligent feedback should allow variability within a certain range, putting the focus more on breathing depth than on precise concurrence with motion. Considering repeatability the master took almost twice the time to perform the individual cycles. This can be the result of longer breaths. But since the cycle duration was not predefined, it cannot be judged. However, lower variation in cycle duration in the beginners constitute better performance in terms of repeatability. The hand movements of the master were more uniform and showed lower variations. Therefore, it can be regarded as a promising feedback parameter. Looking at the accelerations the master achieved lower amplitudes implicating a smoother and less jerky execution with lower variability. This indicates this parameter to be valuable. In this pilot study, only one master was recorded as a reference, thereby limiting statistical interpretations. In future studies the use of data of more than one master is needed to further investigate the four potential feedback parameters and to set viable thresholds. We were able to quantify characteristics of the Qigong movements; however, the mental representation of the Qi flowing through the body might play an equally important role but was not accessed in the current study.

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Corresponding author email: melanie.baldinger@tum.de