



Research on Brain Blood Flow during Taichi-quan by Using fNIRS

Hideyuki KOKUBO^{1,2}, Mikio YAMAMOTO^{1,2}, Hidetsugu KATSURAGAWA², Akihiko KAMADA³,
 Kimiko KAWANO^{4,1,2}, Shuichi HASHIZUME⁵ and Tsuneo WATANABE²

¹ *Institute for Living Body Measurements, International Research Institute (Chiba, Japan)*

² *Center for the Environmental Study of Life and Mind, Faculty of Science, Toho University (Funabashi, Japan)*

³ *Iritech Co., Ltd. (Tokyo, Japan)*

⁴ *Centre for Informatics and Sciences, Nippon Medical School (Tokyo, Japan)*

⁵ *Research Institute, Morinaga & Co., Ltd. (Yokohama, Japan)*

Abstract: The change of brain blood flow was measured by functional near infrared spectroscopy (fNIRS) in subjects during practice of taichi-quan. Subjects were a veteran practitioner (male, 66 years old) and a beginner (male, 59 years old), and they were measured twice. The increase of blood flow was seen in the pre-frontal area in both subjects. Moreover, their patterns of electrodermal activity were similar.

Keywords: taichi-quan, functional near infrared spectroscopy, fNIRS, brain blood flow, electrodermal activity

1. Introduction

The authors measured brain blood flow by functional near infrared spectroscopy (fNIRS) during taichi-quan. fNIRS is the newest non-invasive imaging method which has been developed in Japan and it can be used to measure the cerebral cortex near the scalp (depth: 2-3 cm) with a spatial resolution of 2-3 cm. fNIRS is a suitable method to measure brain activity during taichi-quan. In the present study, the authors describe results, focusing on brain blood flow and electrodermal activity (EDA) during taichi-quan.

2. Methods

Facility: The measurements of brain blood flow and EDA were made on June 28 (session 1) and July 5 (session 2), 2007 at the Institute for Living Body Measurements of the International Research Institute.

Subjects: A veteran practitioner of taichi-quan (K008, male, 66 years old) and beginner (W001, male, 59 years old) were measured in two sessions.

Physiological measurements: Brain blood flow was measured with the OMM-3000 (Shimadzu, Japan)¹⁾ which uses 3 near-infrared lasers (wave-lengths: 780, 805 and 830nm). There were a maximum of 16 emitting and receiving probes. The measurement areas were the pre-frontal and occipital areas. For the second measurement time, electrodermal activity (EDA) and the photoplethysmogram (PPG) of subjects were

also measured with the MP150 (BioPack, USA) at 200Hz. Ag-AgCl electrodes were attached on the second joints of both second and fourth fingers of a subject's left hand, and his skin conductance was measured by the exosomatic method (DC 0.5V constant). The PPG was measured at the tip of the middle finger of the subject's left hand. To prevent change of contact pressures and positions of sensors, sensors were supported by a band and an adhesive plaster, and cables were fixed tightly on the palm and wrist of the subject by an adhesive plaster. Moreover, the pupil reaction was measured with the Iriometer (DM2010, Iritech Co. Ltd., Japan) before and after fNIRS measurements.

Procedure: Measurements of brain blood flow were started after blood flow became stable. The subjects did the following tasks in the first measurement session: taking a pre-rest, listening to music, doing a mental calculation, taking a standing rest, doing standing zen meditation, doing taichi-quan and taking a post-rest. In the second measurement session, the tasks consisted of the following: taking a pre-rest, listening to music, doing a mental calculation, doing a calculation with an abacus, taking a standing rest, doing taichi-quan and taking a post-rest. Each task was 3 minutes in both sessions. Moreover, at intervals between the tasks, a questionnaire with 5-point scales for mental stress, physical stress and tension was answered, and a saliva sample was taken from each subject for measuring salivary Chromogranin A as an index of psychosomatic stress response.

3. Data Analyses

Relative change of brain blood flow was calcu-

Hideyuki KOKUBO kokubo@a-iri.org
 International Research Institute (IRI), 40A, KK Bldg., 1108-2,
 Sonno, Inage, Chiba 263-0051 Japan
 Phone: +81-043-255-8851 FAX: +81-43-255-8852

lated for each task; off set point was 10 s after the start of each task. Data of brain blood flow were averaged for 90-160 s, 20 times, for 59 points with spline compensation.

EDA data were averaged for each 3-min task, and then the logarithm of the ratio of tasks (E_n) to the pre-rest value (E_0) was calculated. Unfortunately, PPG measurements were not successful for subject K008. Therefore, his PPG was not analyzed.

4. Results and Discussions

K008: He showed a large increase of brain blood flow at pre-rest and post-rest, especially, in the first measurement session. He was considered to be unfamiliar with the concept of “experimental rest”. For the tasks of listening to music and doing a mental calculation, brain blood flow increased remarkably. However, EDA declined for the task of listening to music and rose at doing a mental calculation task (**Fig. 1**).

In the standing zen meditation and taichi-quan tasks, brain blood flow increased remarkably for the pre-frontal area (**Fig. 2**). This suggested that mental concentration on tasks occurred²⁻⁵⁾. However, the increase of brain blood flow was not obvious in the second measurement session, and the reason was considered as acclimatization to the experimental procedure.

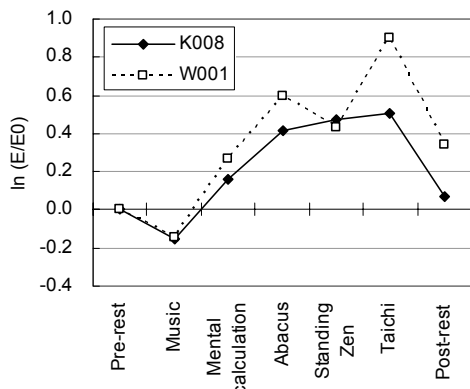


Fig. 1 Relative EDA Change for Pre-Rest

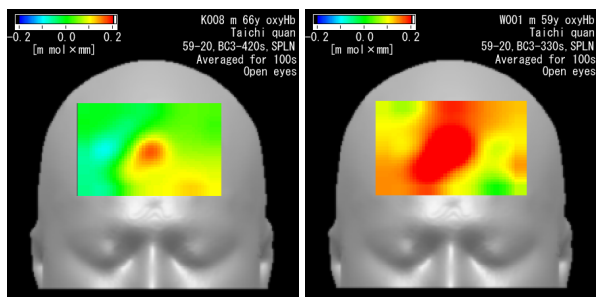


Fig. 2 Oxy-Hemoglobin while doing Taichi-quan in the First Measurement Session (Averaged for 100 s)
 Left: K008 Right: W001

W001: Compared with K008, this subject’s brain blood flow change was not obvious at pre- and post-rests, and also the listening to music task. He was considered as being familiar with the experimental procedure.

Brain blood flow increased for the visual cortex of the occipital area in the second measurement session. Brain blood flow increased at the pre-frontal area for standing zen meditation and taichi-quan tasks in both first and second measurement sessions; the increase was especially remarkable in the first session (**Fig. 2**).

The EDA time transition was similar to that of K008, but task stress was considered to be large for W001 for the tasks of calculation by abacus and doing taichi-quan.

5. Tentative Conclusion

A common point for both subjects was the increase of brain blood flow in the pre-frontal area while doing taichi-quan. Although this study was only preliminary research with 2 subjects, it was concluded that the phenomenon was caused by mental concentration on the task, and the phenomenon declined as subjects became acclimated to the experiments.

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fNIRS による太極拳の脳血流測定

(Research on Brain Blood Flow during Taichi-quan by Using fNIRS)

小久保秀之^{1,2}、山本幹男^{1,2}、桂川秀嗣²、鎌田明彦³、河野貴美子^{4,1,2}、橋爪秀一⁵、渡辺恒夫²
 (Hideyuki KOKUBO^{1,2}, Mikio YAMAMOTO^{1,2}, Hidetsugu KATSURAGAWA², Akihiko KAMADA³, Kimiko
 KAWANO^{4,1,2}, Shuichi HASHIZUME⁵ and Tsuneo WATANABE²)

¹ 国際総合研究機構 生体計測研究所 (日本、千葉)

² 東邦大学理学部 心と生命の環境学研究センター (日本、船橋)

³ アイリテック (株) (日本、東京)

⁴ 日本医科大学 情報科学センター (日本、東京)、

⁵ 森永製菓 (株) 研究所 (日本、横浜)

要旨: 太極拳実施時の脳血流の変化を、近赤外分光血流計を用いて測定した。熟練者 1 名 (男、66 歳) と初心者 1 名 (男、59 歳) を各 2 回ずつ測定した結果、前頭前野の血流増加が共通していた。また、皮膚電気活動の変化パターンは両被験者でよく似ていた。

キーワード: 太極拳、近赤外分光血流計、fNIRS、脳血流、皮膚電気活動

1. はじめに

筆者らは、太極拳実施時の脳血流の変化を多チャンネルの近赤外分光血流計 (functional near infrared spectroscopy: fNIRS) を使って測定した。fNIRS は、日本で開発が進んでいる最も新しい非侵襲計測法である。fNIRS は頭皮近くの大脳皮質しか測れず (頭皮から深さ 2-3cm)、空間分解能も 2-3cm であるが、筋電の影響を無視できるため、太極拳動作中の脳活動を知る有力な方法である。本報は、著者らによる一連の太極拳測定のうち、脳血流と皮膚電気活動の結果のみ報告する。

2. 実験方法

実験場所・期間: 脳血流測定は 2007 年 6 月 28 日、7 月 5 日の 2 日間にわたって、国際総合研究機構 生体計測研究所にて行った。

被験者: 太極拳の熟練者 1 名 (K008、男、66 歳) と初心者 1 名 (W001、男、59 歳) を、各 2 回ずつ測定した。

生理測定: 脳血流測定には、780nm, 805nm, 830nm の 3 波長の光を用いる近赤外光イメージング装置 OMM-3000 (島津製作所製、日本) を用いた¹⁾。送光極、受光極は、それぞれ最大 16 極。測定部位は前頭と後頭とした。また、2 回目

の測定では、皮膚電気活動と脈波も測定した。被験者の左手第 2 指-第 4 指の第 2 節で直流 0.5V 定電圧通電法にて皮膚コンダクタンスを、また、第 3 指第 1 節にて指尖脈波を、それぞれ MP150 (BioPack、USA) にて、200Hz で測定した。センサとケーブルは絆創膏で固定した。また、脳血流測定の前夜で、アイリスメーター DM2010 (アイリテック、日本) で瞳孔対光反応を測定した。

手続き: 脳血流の測定は光ファイバプローブ装着後、血流が十分安定してから開始した。被験者の作業課題は、1 回目は、前安静、音楽聴取、暗算、立位安静、立禅、太極拳、後安静を各 3 分間、2 回目は前安静、音楽聴取、暗算、算盤、立禅、太極拳、後安静を各 3 分間とした。また、各実験課題の間に、緊張感と肉体的・精神的疲労度の質問紙調査 (5 件法)、クロモグラニン A を測定するための唾液採取も行った。

3. 分析方法

脳血流は、各課題開始後 10 秒ほど経過した時点基準とし、そこから 90~160 秒間を 59 点 20 回スプライン補間で加算平均したものを、その課題における血流の相対変化とした。

皮膚電気活動は、各課題 3 分間の平均値を算出し、次に前安静の値 E_0 と各課題の値 E_n の比の対数を求めた。

脈波は有効データが 1 名分しか得られなかったため、分析から除外した。

小久保秀之 kokubo@a-iri.org

263-0051 千葉市稲毛区園生町 1108-2 KK ビル 40A

国際総合研究機構(IRI) 電話 043-255-8851 FAX 043-255-8852

4. 結果と考察

K008: 前安静、後安静の時間帯で脳血流の増加が大きく、特に1回目の測定で脳血流の増加が顕著であった。被験者が、あまり「安静」ということに慣れていなかった可能性がある。

音楽・暗算時の脳血流の増加が著しかった。しかし、暗算時のEDAが高いのに対し、音楽時のEDAは安静時よりも低かった (**Fig. 1**)。

立禅、太極拳時に前頭前野 (第3の目の辺り) で血流増加があり (**Fig. 2**)、課題実施のための意識集中が顕著だったと考えられた²⁻⁵⁾。2回目の測定では、この部位の脳血流増加は目立たず、被験者の実験馴れによるものと思われた。

W001: K008 に比べ、安静時の脳血流変化は目立たず、実験馴れした被験者と思われる。また、音楽時の脳血流増加も目立たなかった。

2回目の暗算で、後頭部の視覚野で血流増加が見られた。立禅、太極拳時の脳血流変化は、1回目、2回目とも前頭前野で血流増加があったが、1回目の増加が特に顕著であった (**Fig. 2**)。

EDA の変化パターンは K008 と似ていたが、特に W001 では算盤と太極拳の課題負荷が大きかったと思われた。

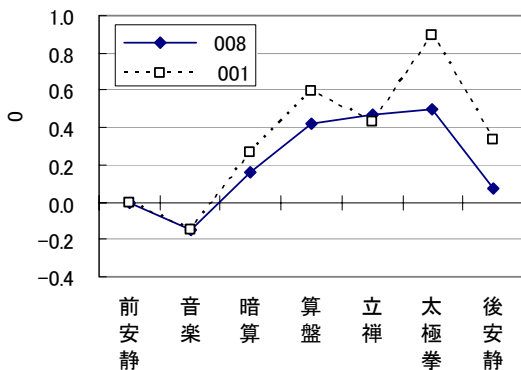


Fig. 1 前安静を基準とした EDA の相対変化

5. 暫定的結論

本測定は被験者 2 名による予備的な測定であるが、両被験者とも、太極拳時に前頭前野 (第3の目の辺り) で血流増加した点が共通していた。これは、課題実施のための精神集中による現象であり、被験者の実験馴れによって増加は目立たなくなると考えられた。

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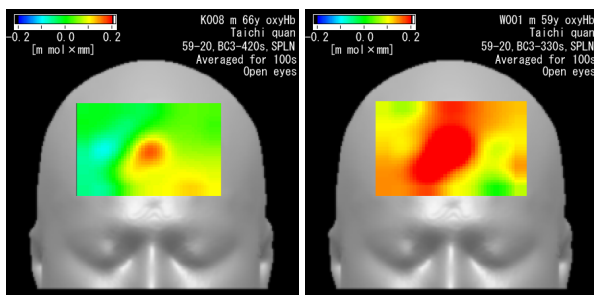


Fig. 2 太極拳 1 回目の酸素ヘモグロビン分布
 左: K008 右: W001 いずれも 100 秒加算平均