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A Study on Physiological Changes in Shaolin Internal Qigong

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Abstract:In this study, the biological reactions of the respiro-circulatory system were analyzed in order to clarify the mechanisms of physiological changes during exercises of Shaolin Internal Qigong. The subject was a 55-year old man, who has practiced Shaolin Internal Qigong for over 40 years. During the exercises, his heart rate ranged from 66 to 77% of the maximum heart rate, the oxygen uptake ranged from 31 to 45% of the maximum oxygen uptake, and the ratings of perceived exertion (R.P.E.) ranged from 4 to 6. Increase of lactate acid in the blood, pulmonary ventilation and respiratory efficiency were recognized to compare with their rest values. Blood pressure and breathing frequency did not change. Thus, these exercises improved respiratory efficiency by the maximum isometric muscle contraction while they maintained natural breathing. In addition, Shaolin Internal Qigong was considered to influence the reflex system because it inhibited both blood pressure increase and respiratory rate change which are usually observed during the maximum isometric muscle contraction.

Keywords: Shaolin Internal Qigong, respiratory efficiency, blood pressure, heart rate, oxygen uptake, isometric muscle contraction

1. Introduction

In China, Shaolin Internal Qigong is utilized to improve physical fitness and treat life-style diseases. Shaolin Internal Qigong is based on three kinds of posture (Posture is a dynamic exercise[1)] which of Up-right Standing, Horse-riding Standing and Forward Lunge Standing) and four kinds of motion (Pushing Eight Horses Forward, Wind Swaying the Lotus Leaf, Pulling Nine Oxen Backward and Overlord

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Holding-up the Tripod) . However, Shaolin Internal Qigong differs from training for the breathing methods and meditation of general qigong practice. It is characterized as performance of natural breathing, and so qi leads the force by maintaining maximum isometric muscle contraction.

Studies of qigong methods have concentrated on Static Exercise from physio-psychology[2-6], but Dynamic Exercise like Shaolin Internal Qigong has had little study. In this report, biological reactions of the respiro-circulatory system as changes of the physical state were analyzed on a master of Shaolin Internal Qigong during exercises, and their influences on the body's physiological functions were discussed.

2. Methods

1. Subject

The subject was a 55-year old who has practiced Shaolin Internal Qigong for more than 40 years. Table 1 shows his physical characteristics. The body fat was measured with a fitness analyzer BFT-2000 (Kett Co., Tokyo, Japan).

2. Informed consent

The subject gave his informed consent to participate in this study.

3. Exercise stress testing

The resting metabolic rate, heart rate and oxygen uptake for 5 minutes were measured. The heart rate was measured from R-R intervals recorded on ECGs displayed on a pen oscillograph (8K13-1S-ME, Sanei Co., Tokyo, Japan) .

Table 1 Physical Characteristics of Subject

Height (cm)	Weight (kg)	BMI	%Fat (%)
182.5	77	23.1	20.5

Oxygen uptake was measured from the expiration gas by a breathing metabolism system aeromonitor (AE-300S, Minato Co., Tokyo, Japan) . The exercise stress was measured using a treadmill (NT-12, Nishiokakotetsu Co., Tokyo, Japan) to reach exhaustion by incremental loading. Oxygen uptake, heart rate, pulmonary ventilation, respiratory rate and rating of perceived exertion (R.P.E.) were consecutively recorded during the stress test [7,8]. The R.P.E. was accorded to the index of Borg[9]. Table 2 shows the protocol of the exhaustion test.

Table 2 Protocol of Exhaustion Test

time (min)	1	2	3	4	5	6	7
tredmill speed (m/min)	80	80	80	120	120	120	160

4. Shaolin Internal Qigong

The subject did Posture of Up-right Standing for 5 minutes, and Pushing Eight Horses Forward, Pulling Nine Oxen Backward, and Overlord Holding-up the Tripod for 10 minutes each. Oxygen uptake, heart rate, pulmonary ventilation, respiratory rate and R.P.E. were recorded during this time. In addition, blood pressure and lactic acid in the blood were measured at pre, post and 10 minutes after these

exercises. The blood pressure was measured with a Riva-Rocci type mercury sphygmomanometer. The lactic acid in the blood was measured using a Lactate Pro (LT-1710 TM, KDK Co., Kyoto, Japan) placed on a fingertip[10,11].

5.Postures and Motions of Shaolin Internal Qigong

Form 1: Posture of Up-right Standing

For this posture, the subject did the following. Set the feet apart a little wider than the shoulders, with the toes turned a inward (splay feet). Breathe naturally for a few minutes and set the feet with "hegemonic force" on the ground with the head upright, the eyes looking straight ahead, the shoulders dropped, chest pushed out to get the scapulae closer to the spinal column, the lower abdomen contracted, the buttocks tucked in, and the arms akimbo (fingers in the front and the thumb at the back). The arms face the floor, with the fingers closed and stretched, and the two thumbs positioned forcefully to form a right angle. At the same time the arms are stretched backward at 30 degrees and the wrist joints bent backward.

Form2: Pushing Eight Horses Forward and Pulling Nine Oxen Backward

For these motions, the subject did the following. Stand erect and take posture of Up-right Standing. The elbows are bent at 90 degrees, with palms facing upwards and the thumbs stretched to form a right angle with the fingers. Breathe naturally for a few minutes. Then, direct strength to the arms and the fingertips. Push the arms forward slowly while turning the palms to get them facing each other, with the thumbs pointing upward. Continue pushing until the elbows are straight. Slowly turn the forearms inward to get the back of the hands facing each other and the thumbs pointing downward. Turn the palms into tight fists and withdraw the hands while turning the forearms outward as if pulling a strong ox by the tail. When the fists reach the hypochondria, open them into palms which face upward .

Form3: Overlord Holding-up the Tripod

For this motion, the subject did the following. Stand erect and take posture of Up-right Standing. The elbows are bent at 90 degrees, with palms facing upwards and the thumbs stretched to form a right angle with the fingers. Breathe naturally for a few minutes. Then, with the palms facing upward, raise the arms slowly as if holding up a heavy object. When the palms are at chest height, turn the arms gently inward while stretching them until they are straightened, at the same time, get the fingers of the two hands pointing at each other, palms facing upward, with middle fingers close to each other, the thumbs as widely apart from each other as possible, and the head raised up to see the middle fingers. Perform the "Tripod" with force 5 minutes, then rotate the forearms gently to get the palms facing each other, fingertips pointing upward. Lower the palms with force along the chest until they reach the hypochondria.

3. Results

The BMI and %Fat of the subject were within the standard range for Japanese of the same age[12].

The average heart rate at rest in a sitting position for 5 minutes was 112.8 ± 1.7 beats/min (b/min) and the average oxygen uptake was 297.4 ± 11.8ml/min. The maximum heart rate at exhaustion with the exercise load was 186 b/min and the maximum oxygen uptake was

2,494ml/min.

The heart rate and the oxygen uptake during the exercise load test showed a high correlation (r=0.973), as did the heart rate and the R.P.E. (r=0.953).

The respiro-circuratory functions before Posture of Up-right Standing were obtained as the following values. The heart rate was 88b/min, the oxygen uptake was 324ml/min, systolic blood pressure was 134mmHg, diastolic blood pressure was 80mmHg, and lactic acid in the blood was 1.6mmol/l. During Posture of Up-right Standing, the average heart rate was 133.8 ± 1.3b/min, the maximum heart rate was 136b/min, the average oxygen uptake was 775.4 ± 43.5ml/min, and maximum oxygen uptake was 854ml/min (**Fig.1**). The average respiratory rate was 14.4 ± 0.5times/min and the average respiratory efficiency was 29.4 ± 1.4ml/l (**Fig. 2**).

After Posture of Up-right Standing, the systolic blood pressure was 142mmHg, the diastolic blood pressure was 92mmHg and the lactic acid in blood was 2.8 mmol/l. Posture of Up-right Standing was recognized to increase by the diastolic blood pressure 8mmHg, the systolic blood pressure 12mmHg, and the lactic acid in blood 1.2mmol/l comparing with those at rest.

After 10 minute recovery of Posture of Up-right Standing showed a little decrease of all factors, the systolic blood pressure was 138mmHg, the diastolic blood pressure was 84mmHg, and the lactic acid in blood was 2.1mmol/l.

The respiro-circuratory functions before the motions Pushing Eight Horses Forward, Pulling Nine Oxen Backward and Overlord Holding-up the Tripod were obtained as the following values. The heart rate was 86b/min, the

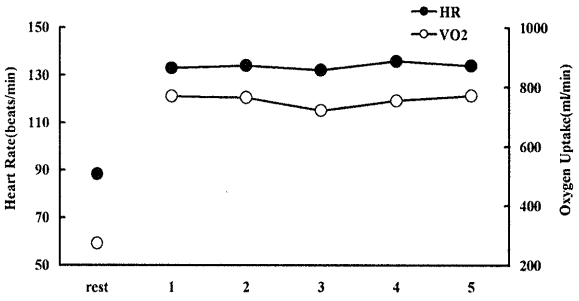

Fig.1 Changes of heart rate and oxygen uptake during Shaonlin Internal Qigong-Posture of Up-right Standing

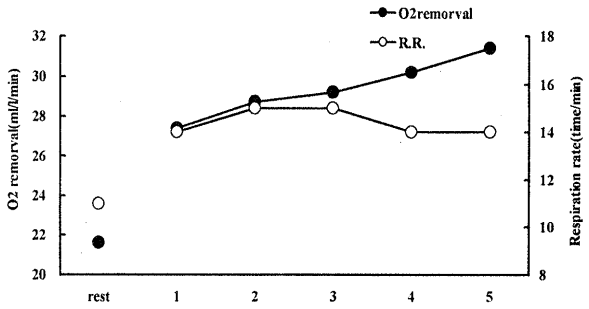

Fig.2 Changes of O_2 removal and respiratory rate during Shaolin Internal Qigong--Posture of Up-right Standing

oxygen uptake was 353ml/min, systolic blood pressure was 122mmHg, diastolic blood pressure was 86mmHg, and lactic acid in the blood was 2.3mmol/l. During motions of Pushing Eight Horses Forward and Pulling Nine Oxen Backward, the average heart rate was 123 ± 7.3b/min, the maximum heart rate was 132b/min, the averege oxygen uptake was 922 ± 117.2ml/min, and maximum oxygen uptake was 1052ml/min. The R.P.E. 2 minutes after beginning the motions Pushing Eight Horses Forward and Pulling Nine Oxen Backward was level 4, it did not change later and was the same on ending the exercise. During the motion Overlord Holding-up the

Tripod, the average heart rate was 143 ± 1.8b/min, the maximum heart rate was 146b/min, the averege oxygen uptake was 1114.2 ± 27.6ml/min, and maximum oxygen uptake was 1160ml/min. The R.P.E. 2 minutes after beginning this motion was level 5, and it was level 6 at the end.

After Pushing Eight Horses Forward and Pulling Nine Oxen Backward, and Overlord Holding-up the Tripod, the systolic blood pressure was 138mmHg, the diastolic blood pressure was 96mmHg and lactic acid in the blood was 4.0mmol/l.

These motions were recognized to increase the systolic blood pressure 16mmHg, the diastolic blood pressure 10mmHg, and lactic acid in the blood 1.7mmol/l compared to their values at rest.

After a 10 minute recovery on ending these motions, there was a little decrease of all factors: the systolic blood pressure was 134mmHg, and the diastolic blood pressure was 86mmHg, but lactic acid in the blood did not change.

4. Discussion

Shaolin Internal Qigong is a Dynamic Exercise for regulating the body and mind. It differs from the general qigong methods which regulate breathing and the mind by Static Exercise and it also differs from other Oriental fitness practices[13,14].

In Shaolin Internal Qigong, it is most important to keep the special postures by maximum isometric muscle contraction and at the same time to breathe naturally so as to obtain mind-control.

On the other hand, physiological studies on Shaolin Internal Qigong are rare, despite its unique characteristics. The subject of this study has been doing Shaolin Internal Qigong for over 40 years, and so he is a skilled master at the highest level. In this study, the physiological changes on doing Shaolin Internal Qigong exercises were measured at pre, during and post phases and compared with those at rest.

Breathing phase and breathing itself were not recognized to show any remarkable change in any phases of the exercises. Moreover, phenomena such as coughing or breathing inhibition which are usually observed during isometric muscle contraction were not recognized.

The heart rate and oxygen uptake increased to two or three times their rest value, but the blood pressure showed only a rise of 10mmHg degree. The volume of pulmonary ventilation increased to about 2.5 times the rest value, and oxygen uptake rate (O_2 removal) improved conspicuously.

For improved oxygen uptake rate (O_2 removal), increase of pulmonary ventilation is closely related to getting more of oxygen uptake per minutes. Generally an increase of equal volume of pulmonary ventilation reflects respiratory efficiency, so it seemed that respiratory efficiency was increased because improved pulmonary ventilation was observed.

As factors for oxygen uptake rate improvement, internal environmental changes are related to the partial pressure of CO_2 in the blood , the H^+ of the respiratory reflex center, and the arterio-venous oxygen difference. It was guessed that Shaolin Internal Qigong effectively controls such internal environmental changes.

As mentioned above, it became clear that Shaolin Internal Qigong could raise the oxygen uptake rate while restraining breathing frequency

and blood pressure for the condition of maximum isometric muscle contraction. Shaolin Internal Qigong seems to have a biofeedback mechanism to control the isometric muscle contraction, respiration and visceral reflexs depending on consciousness.

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少林内功の生理的動態に関する研究

(A Study on Physiological Changes in Sholin Internal Qigong)

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要旨：　本研究は、少林内功試行時における生理的動態を明らかにするため、呼吸循環器系機能の反応を分析した。被検者は、少林内功の修練年数40年以上の経験を持つ55歳の男性1名である。少林内功試行中の心拍レベルは、最大心拍数の66%～77%の範囲を示し、酸素摂取量は31% ～45%の範囲であった。主観的運動強度は、レベル4～6の範囲であった。血中乳酸濃度は、安静初期値より少林内功によって2.8～4.0mmol/lの増加が認められた。換気量は、安静初期値に対し15.4l/minの増加が認められた。呼吸効率は、安静初期値に対し9.5ml/lの増加が認められた。血圧および呼吸数は、安静時に対しほとんど変化が認められなかった。

以上より、少林内功試行は、最大等尺性筋収縮を行いながらも、自然呼吸によって呼吸効率を向上させていることが明らかとなった。また、少林内功は、最大等尺性筋収縮時に認められる収縮期血圧の上昇を抑制し、呼吸数の変化も認められないことから、内臓系反射の働きに何らかの影響を及ぼすものと推察できる。

Keywords: Shaolin Internal Qigong, respiratory efficiency, blood pressure, heart rate, oxygen uptake, isometric muscle contraction

1．はじめに

中国において少林内功は、身体適応能や生活習慣病に対する予防と治療の手段として有効に活用されている。少林内功は、主に３種の襠勢（站襠・馬襠・弓箭襠）と４種の動作（前推八匹馬勢・風擺荷葉勢・倒拉九頭牛勢・覇王挙鼎勢）を基本とし、気功の動功に属されている[1)]。しかし、一般の気功法のように呼吸（吐納）法や瞑想を修練内容の中心とするものと異なり、等尺性筋収縮を維持しながら「呼吸自然・以気導力」を行うのが特徴とされている。

気功法の研究は、静功に関して生理心理学的な側面から数多くの研究が行われているが[2,3,4,5,6)]、少林内功のような動功に関する研究は極めて少ない。

本研究では、少林内功熟練者１名の少林内功試行時における生理的動態について呼吸循環器系機能の反応を分析し、少林内功の修練が生体にどのような影響を及ぼすのかについて検討した。

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2．方　法

1.被検者

被検者は、55歳の男性で少林内功の修練年数40年以上の経験者１名であった。

被検者の身体的特徴は、表1に示す通りである。体脂肪は、フィットネスアナライザー（ケット科学研究所製：BFT-2000）により測定した。

Table 1 Physical Characteristics of Subject

Height(cm)	Weight(kg)	BMI	%Fat(%)
182.5	77	23.1	20.5

2.実験の承諾

被検者には、インフォームドコンセントにより本研究の趣旨を口頭で説明し、文書にて承諾を得た。

3.運動負荷検査

被検者には、安静椅座位5分間の心拍数と酸素摂取量を測定した後、運動負荷検査を行った。

心拍数は、胸部双極誘導法より測定し、ペンオシログラフ（三栄測器社製:8K13-1S-ME）で記録し、心電信号R波のR-R間隔より算出した。酸素摂取量は、呼気ガスを呼吸代謝システムエアロモニター（ミナト医科学社製:AE-300S）より分析し求めた。

運動負荷は、トレッドミル（西川鉄鋼社製：TREAD-MIL:NT-12）を用いて漸増負荷法によりExhaustion testを行い酸素摂取量、心拍数、換気量、呼吸数及び主観的運動強度（Rating of Perceivede Exertion：以下RPEとする)をExhaustionに至るまで連続記録した[7,8]。主観的運動強度は、Borgの指標を用いた[9]。Exhaustion testのプロトコールは、表2に示す通りである。

Table 2 Protocol of Exhaustion Test

time (min)	1	2	3	4	5	6	7
speed (m/min)	80	80	80	120	120	120	160

4.少林内功

少林内功は、站襠勢を5分間、前推八匹馬勢及び倒拉九頭牛勢と覇王挙鼎勢を10分間行い、少林内功中の酸素摂取量、心拍数、換気量、呼吸数及び主観的運動強度を連続記録した。また、少林内功の前後及び少林内功の10分後に、血圧及び血中乳酸を測定した。血圧は、Riva-Rocci型水銀血圧計で測定した。血中乳酸濃度は、ラクテート・プロ（京都第一科学社製：LT-1710 TM）を用いて指尖部より採血を行い測定した[10,11]。

5.少林内功の姿勢と動作

1)站襠勢（たんとうせい）

立位姿勢で両足の足尖を接触させ、足踵は15cm程度の間隔を保ち自然呼吸を整える。その後、左足を横方向に肩幅の間隔に開く。両足尖は、内「八字」方向に向き五本足趾を覇力し、立位姿勢を保持する。胸部は、やや前方に突き出し、殿部は収縮させる。両腕は、両肘を真っ直ぐにした状態で30度後方伸展し、両手首は背屈させ、四指を並び合わせ、拇指は外展させる。

2)前推八匹馬勢（ぜんすいはっぴきばせい）及び倒拉九頭牛勢（とうろうきゅうとうぎゅうせい）

站襠勢より肘を90度屈曲させ、四指を並び合わせ、拇指は外展させた状態で直掌にし、体幹の両側面に手掌を置き自然呼吸を整える。その後、手のひらは、蓄えた力を入れながら体幹より前方に徐々に押し出し、両肘を完全に伸展させた後、両腕を内旋させ、手のひらは拳にしてから蓄えた力を入れながら両肘を元の位置に戻す。

3)覇王挙鼎勢（はおうきょていせい）

站襠勢より肘を90度屈曲させ、手掌を上方に向かせ、四指を並び合わせ、拇指は外展させた状態で体幹の両側面に置き自然呼吸を整える。両手掌は、蓄えた力を入れながらゆっくりと上方へ押し上げ、胸元の高さに到達したら両手掌を内転し上方に向かせ

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両肘を完全に伸展させた後、両手首を背屈させ、両中指を接触させ、両眼は中指を凝視した状態を数分保持し、站襠勢に戻す。

3．結　果

被検者のBMI及び%Fat値は、日本人の同年齢の標準範囲内にあった[12]。

椅座位安静時（５分間）の平均心拍数は、112.8±1.7 beats/min（以下b/minとする）、平均酸素摂取量は、297.4±11.8ml/minを示した。

運動負荷の Exhaustion 時の最大心拍数は、186b/minで、最大酸素摂取量は、2,494ml/minを示した。運動負荷検査において得られた心拍数と酸素摂取量の間には、高い相関関係(r=0.973)が認められた。また、心拍数とRPEの関係にも、高い相関関係(r=0.953)が認められた。

站襠勢試行前の呼吸循環機能は以下のような値が得られた。安静時では、心拍数88b/min、酸素摂取量324ml/min、収縮期血圧134mmHg、拡張期血圧80mmHg、および血中乳酸濃度1.6mmol/lを示した。

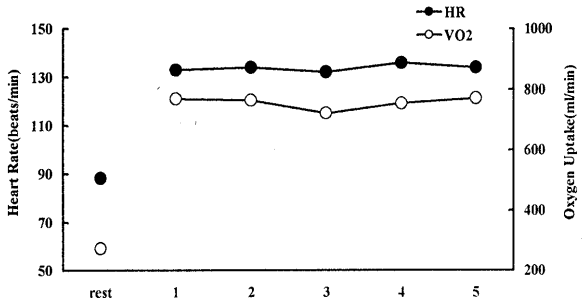

Fig.1 Changes of heart rate and oxygen uptake during Shaonlin Internal Qigong-Posture of Up-right Standing

站襠勢時では、平均心拍数133.8±1.3b/min、最大心拍数136b/minとなり、平均酸素摂取量775.4±43.5ml/min、酸素摂取量の最大値は854ml/minが示された（Fig.1）。站襠勢時の呼吸数は、平均14.4±0.5times/minを示し、呼吸効率は平均29.4±1.4ml/lを示した（Fig.2）。

站襠勢後では、収縮期血圧142mmHg、拡張期血圧92mmHg、および血中乳酸濃度2.8 mmol/lを示した。

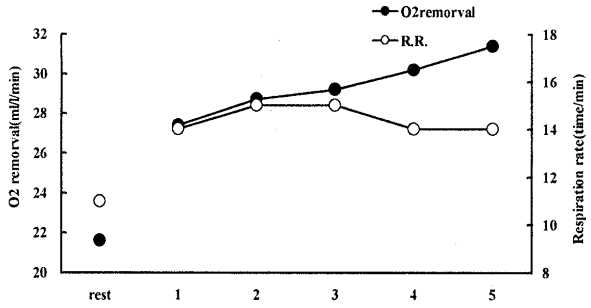

Fig.2 Changes of O_2 removal and respiration rate during Shaolin Internal Qigong-Posture of Up-right Standing

安静初期値に対して収縮期血圧8mmHg、拡張期血圧12mmHg、血中乳酸濃度1.2mmol/lの増加が認められた。回復10分後では、収縮期血圧138mmHg、拡張期血圧84mmHg、血中乳酸濃度2.1mmol/lとなり、いずれもわずかに減少を示した。

前推八匹馬勢及び倒拉九頭牛勢と覇王挙鼎勢前の呼吸循環機能は以下のような値が得られた。安静時では心拍数86b/min、酸素摂取量353ml/min、収縮期血圧122mmHg、拡張期血圧86mmHg、および血中乳酸濃度2.3mmol/lを示した。前推八匹馬勢及び倒拉九頭牛勢時では、平均心拍数123±7.3b/min、最大心拍数132b/minを示した。平均酸素摂取量922±117.2ml/min、酸素摂取量の最大値は1,052ml/minが示された。RPEは、前推八匹馬勢及び倒拉九頭牛勢開始2分後にレベル4を示し、動作終了時での変化は認められなかった。覇王挙鼎勢時では、平均心拍数143±1.8b/min、最大心拍数146b/min、平均酸素摂取量1,114.2±27.6 ml/min、酸素摂取量の最大値は1,160ml/minが示された。RPEでは、覇王挙鼎勢開始2分後にレベル5を示し、後動作終了時にはレベル6を示した。

前推八匹馬勢及び倒拉九頭牛勢と覇王挙鼎勢後では、収縮期血圧138mmHg、拡張期血圧96mmHg、および血中乳酸濃度4.0mmol/lを示した。安静初期値に対して、収縮期血圧16mmHg、拡張期血圧10mmHg、および血中乳酸濃度1.7mmol/lの増加が認められた。回復10分後では、収縮期血圧134mmHg、拡張期血圧86mmHgを示し、収縮期及び拡張期ともわずかに減少を示した。血中乳酸濃度は、動作終了10分後も顕著な変化は認められなかった。

4．考　察

少林内功の姿勢および動作は、静功を主とする一般的な気功法とは異なり、最大等尺性筋収縮による姿勢保持と自然呼吸およびマインドコントロールにより、調心身を行うのが最大の特徴とされる。東洋の健身術は、呼吸法による調整が主となるが、それとは異なる少林内功の生理学的研究は、ほとんど報告がみられない[13,14]。

本研究の被検者は、40年以上の経験を有する世界的にみても少林内功を高い水準で会得している数少ない熟練者であるといえる。

今回は、生理学的指標を用いて安静初期値に対する少林内功試行時の変化を分析した。

呼吸相および呼吸数は、安静時と比べて少林内功試行時も顕著な変化が認められず、筋収縮時にみられる堵咳や呼吸抑制は認められなかった。

心拍数、酸素摂取量は、安静初期値より２～３倍に増加していたが、血圧は10mmHg程度の上昇となっていた。換気量は、安静初期値より約2.5倍に増加し、酸素摂取率(O_2 removal)は顕著に向上していた。

酸素摂取率の向上には、単位酸素摂取量を得るのに必要な換気等量が密接に関係している[7,8,11]。この換気等量は、呼吸効率の指標となっており、換気等量の増加はいわゆる呼吸効率の向上が認められたと考えられる。酸素摂取率向上の要因として、血液中のCO_2分圧、呼吸中枢のH^+および動静脈酸素較差など内部環境の影響が考えられる。少林内功は、これら内部環境のコントロールに効果的な要因が含まれるものと推察できる。

以上、少林内功は、強度な等尺性筋収縮状態において、呼吸および血圧抑制しながら酸素摂取率を高めていることが明らかとなった。

これらのことから、少林内功は等尺性筋収縮、呼吸、および意識によって内臓系反射の制御を可能とするバイオフィードバック法であるとも考えられる。

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