種々な条件が筋力発揮に与える影響について

(第2報：水中における筋力測定)

The degree of muscular strength by conditions of measurements
(2nd report : measurements in water)

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筋力を発揮することが難しい条件を設定するために、被検者が立位で完全に浸水する水槽のなかで筋力測定を行ない、この結果から宇宙飛行中にどのような方法で運動をさせることができるかということを調べるための基礎的資料を得ることを目的とした。

被検者は健康な男子学生4名であった。筋力の測定は上肢：伸展力、屈曲力、内転力、外転力　下肢：伸展力、屈曲力、背屈力底屈力であった。水中での測定による不安の影響を観察するために、4名の被検者すべて3種類の条件による筋力測定を日を変えて5回以上行った。結果として、3回以上の測定をすれば筋力測定の数値に大きな変動が見られなくなるので、これ以後のデータは種々の分析に使えることが示された。脚伸展力の平均値が標準の数値よりも17kg (50.46kg) 低かったが、これはからだの固定、とくに上半身の固定が十分になされていなかったことによるものだろう。水中での測定で最も数値の低下の大きかったものは脚伸展力であり、地上の68.1%が水中で発揮できる最大のものであった。上肢の筋力は水中でも大きな低下を示さなかった (87%～103%). これは上肢の筋力が大きなものではないことから姿勢を維持するための体重の役割がそれほど大きくないからである。今回の実験では太腿をベルトで締め付けること、両手で筋力測定の装置を摑むことがからだの固定の補助となったのだが、水中での筋力に大きな低下が見られなかった。これらの結果から、無重力での生活が筋萎縮を引き起こすことの対抗策として筋力トレーニングを取入れようとしたとき、そのトレーニング設備を作ることはそれほど難しいものではないだろう。

Our ability to stand upright has not been without cost and has been made possible only through the development of an antigravity muscle system. During the space flight, rapid atrophy of skeletal muscles occurs.

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There are several countermeasures, including muscular training, taken against atrophy.

The purpose of this study is to measure muscular strength in water, where exerting force via muscle contracation is more difficult than in air.

METHODS

Four healthy students were used as subjects. A multipurpose muscular strength instrument (Takes Co.,Ltd.) was used to measure muscular strength in air and water. Measurement of the upper and lower extremity included two paramaters respectively : extention-flexion, abduction-adduction in the upper, extension-flexion, dorsi-flexion-planter-flexion in the lower.

Before measurements, the subjects were instructed how to perform each a muscular contraction and then did warm-ups on the experimental equipment. They were told before hand to exert maximum effort but during measurements, no encouragement was given. For each measurements, subjects did two repetitions followed by a 1-minute rest. The larger value of measurements was recorded as muscular strength in each extremity. Subjects did experiments at least 5 times in air on 5 different days and then repeated these exercises in water. For the measurements in water, they could respire through an air-tank using scuba-diving equipment.

Measurements were taken as follows :

Ⅰ. Measurements of muscular strength

A. Measurements in air

Subjects sat on a chair and then tightened their thighs with a broad belt, which made them use maximum muscle contraction. For maintaining each contraction, they grasped a perpendicular bar.

B. Measurements in water (1)

Measurements in water were done the same way as in air.

C. Measurements in water (2)

In the condition without sitting in chair, subjects did experimental exercises with the help of only grasping a bar.

Ⅱ. Measurements of working reach in upper extremity

A. Measurements in air

Subjects was stood in front of a board and drew a circle as large as possible against a given load which pulled him back.

B. Measurements in water

Measurements were done as same way as in air.

RESULTS

Ⅰ. Measurements of three kinds of conditions in muscular strength

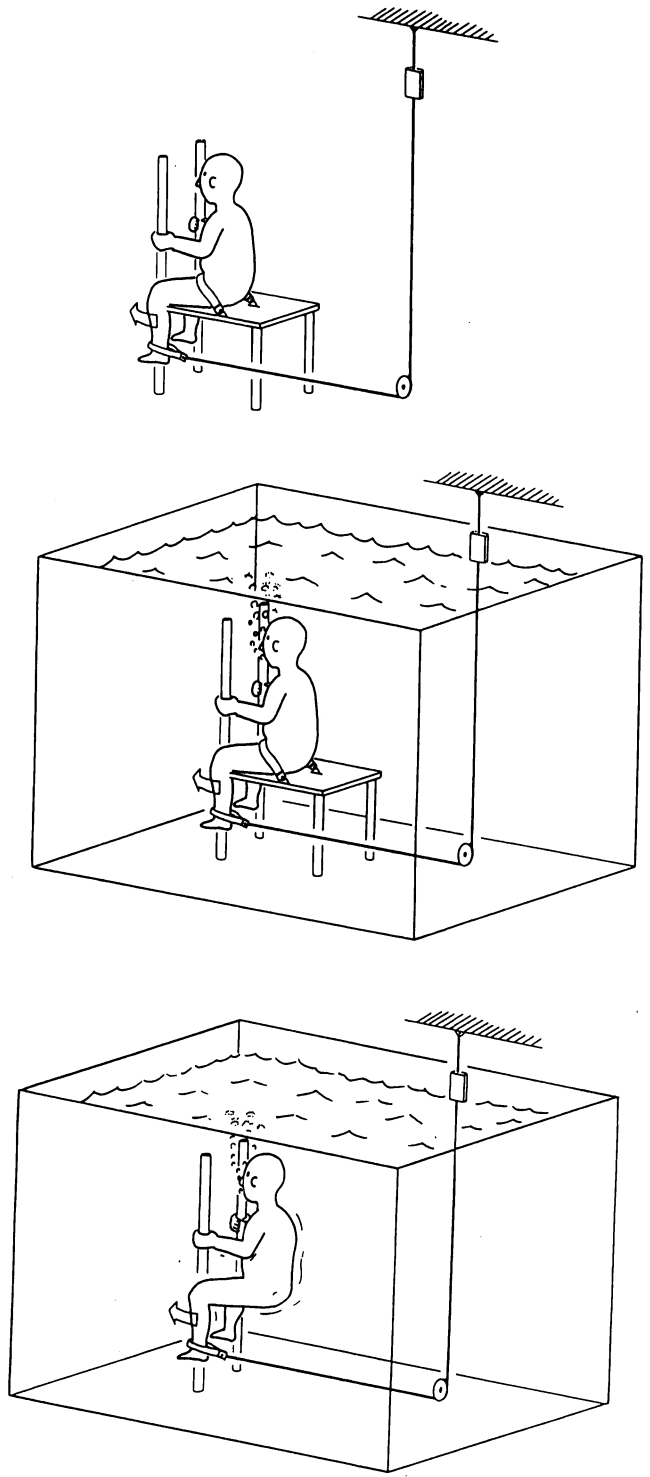

Figure 1 Experimental views of three kinds of measurements

Upper extremity (Upper arm)	in air mean	SD,kg	in water(I) mean	SD,kg	in water(II) mean	SD,kg
Extension	20.25	1.65	18.36	3.37	6.76	2.99
Flexion	33.22	7.71	29.12	12.00	6.53	4.02
Adduction	26.48	5.04	27.30	5.10	9.00	4.16
Abduction	43.10	8.06	38.88	9.94	10.50	2.53
Lower extremity (Knee & Ankle)						
Extension	50.46	9.87	34.38	9.54	6.81	4.92
Flexion	24.27	5.36	20.40	4.45	8.12	3.17
Dolsi-flexion	28.50	3.11	23.10	6.11	12.77	10.18
Planter-flexion	20.25	1.65	18.36	3.37	6.76	2.99

Table 1 Mean values and standard deviation of muscular strength in three kinds of mesurements

In order to gain accurate data of muscular strength, subjects performed the same exercises more than five times for test-retest, which was because of by unreliability of the measurements in water (Fig.1). Figure 2 shows the results of knee extension-flexion on five different days. There was a big difference in the values between the first measurement and second one, but the results in water showed not significant variation. In terms of arm extension-flexion on five different days, there were also not big changes in the values after the third measurements. From the results of the pretest, we realized that we could obtain reliable data of muscular strength in water if subjects practiced a several times.

The results of knee extension in air were 50.46 ± 9.87kg (mean and SD), which was 8kg lower than which Suzuki (2) has reported. In the measurement in water which we tried the first time, the values of knee extension showed 34.38 ± 9.54kg, which was only 68.1% of the values in air. However, in the case of the unrestricted thigh, subjects could only put out 6.81kg of exertion, i.e., 13% of the maximum in air.

On the other hand, in dorsi-flexion and planter-flexion of the foot, the value of dorsi-flexion of water (95.6% of maximal in air) was not effected, but planter-flexion was showed a value 20% lower that in air.

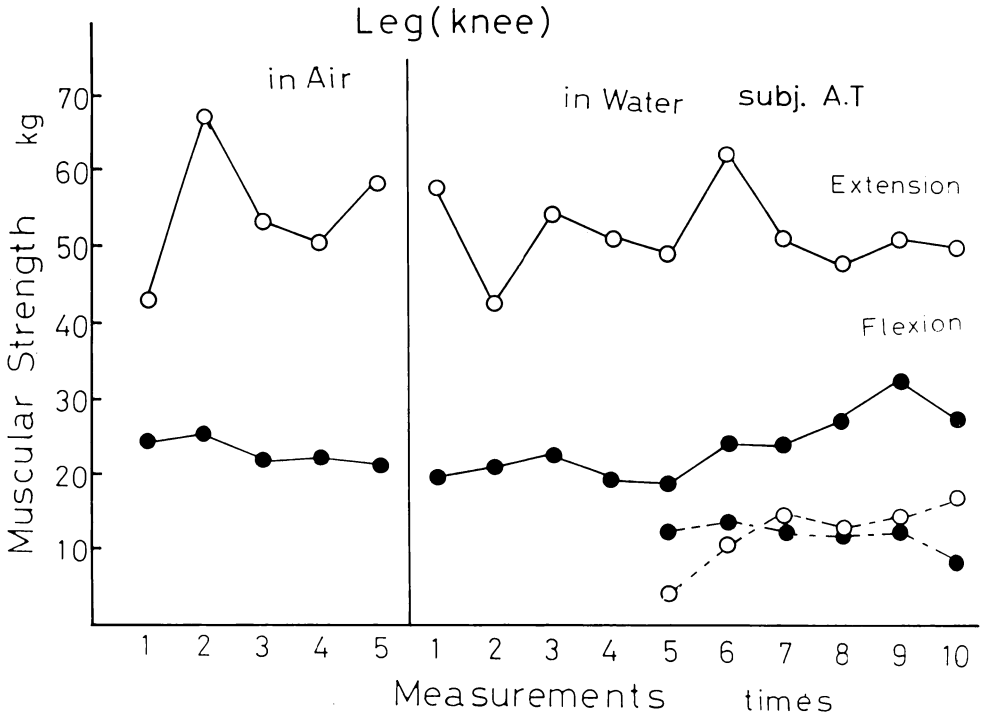

Figure 2 Changes of muscular strength in knee extension and flexion based on different days

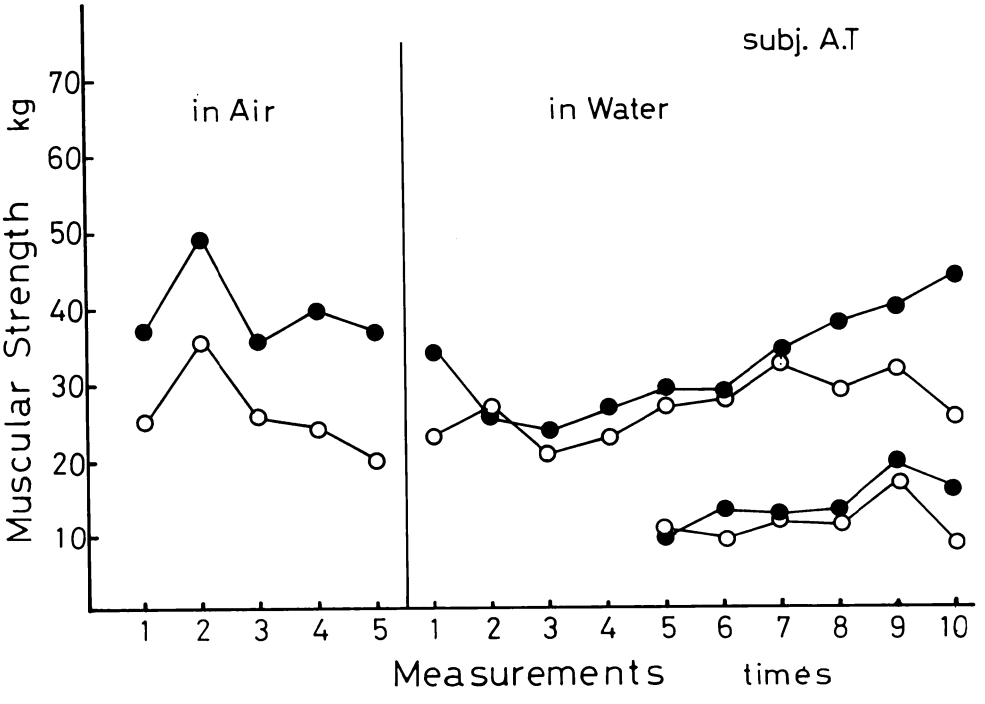

Figure 3 Changes of muscular strength in upper arm extension and flexion due to different days

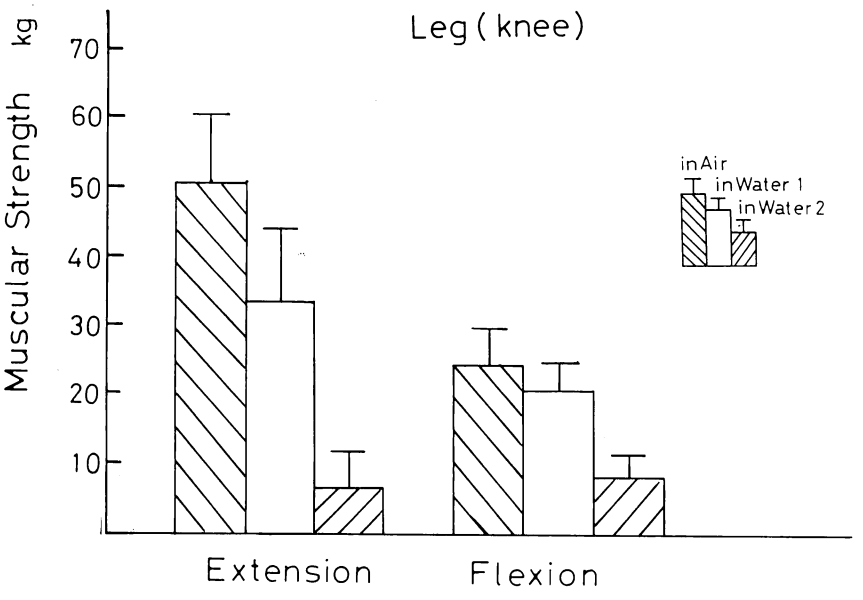

Figure 4 Mean values and standard deviation of extension and flexion of knee in three kinds of measurements

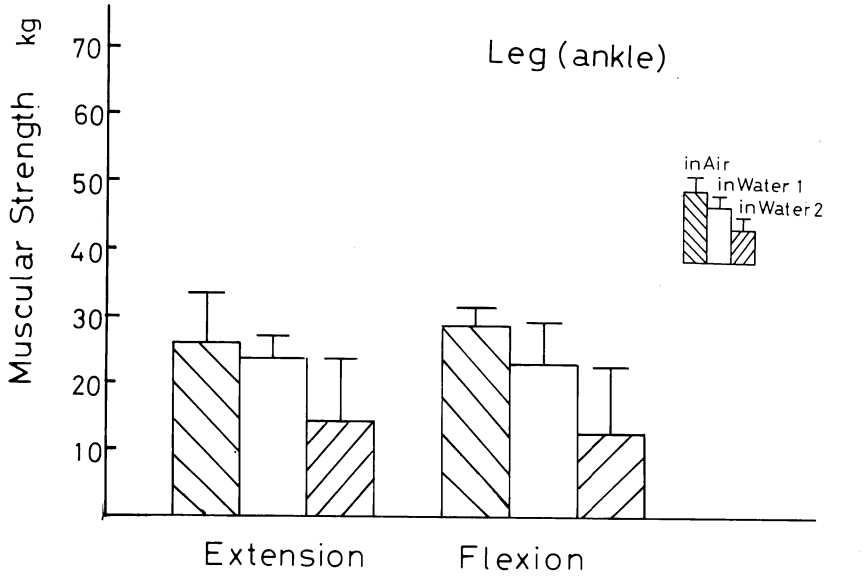

Figure 5 Mean value and standard deviation of extension and flexion of ankle in three kinds of measurements

In measurements of the upper extemity, the results of muscular strength in extention-flexion and adduction-abduction are shown in figures 5 and 6. The mean value of extension in water (18.36kg) was 10% lower than the value in air (20.25kg), but the two conditions, air and water, were obtained similar results of flexion (29.12kg vs 33.22kg).

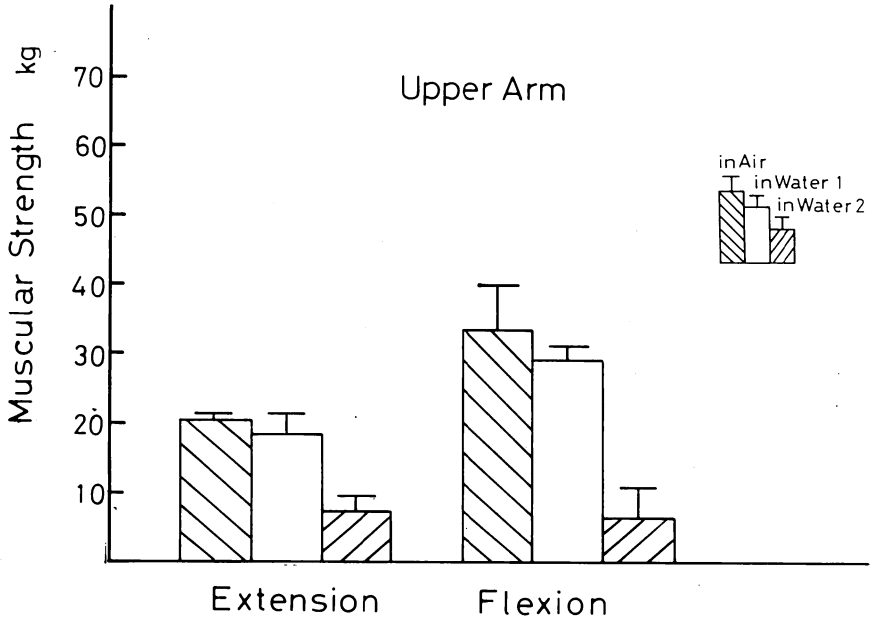

Figure 6 Mean value and standard deviation of extension and flexion of upper in three kinds of measurements

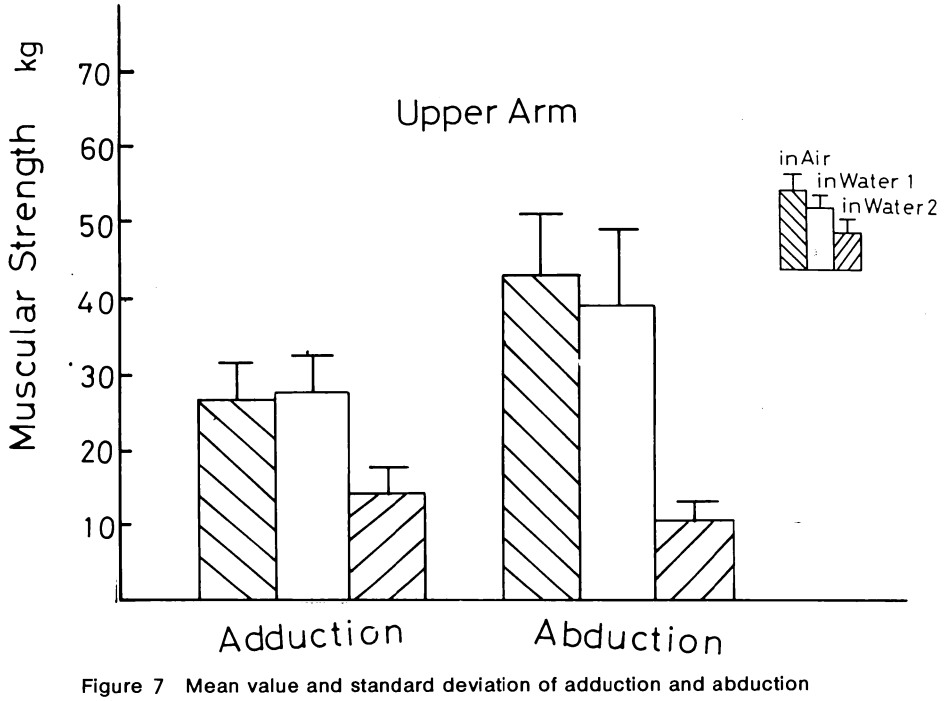

Figure 7 Mean value and standard deviation of adduction and abduction of upper arm in three different kinds of measurements

Furthermore, adduction in water showed a 3% larger value in air. Although there is not a significant difference between the values in water and in air, adduction in the upper arm was the only exertion which was not effected absolutely in water.

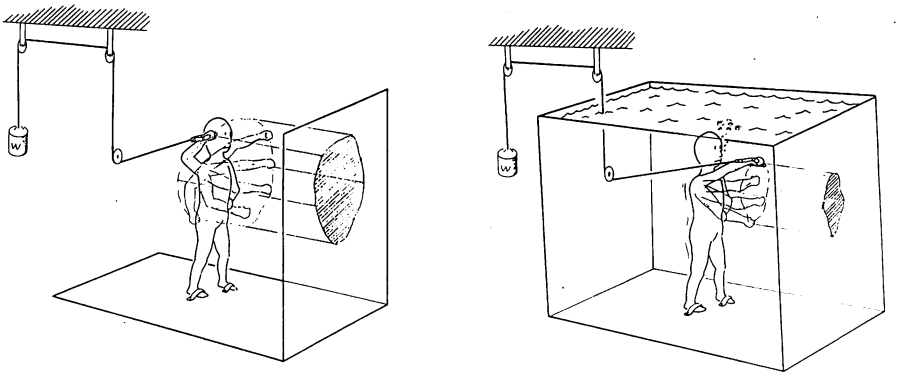

Figure 8 Experimental view of working capacity of upper extermity

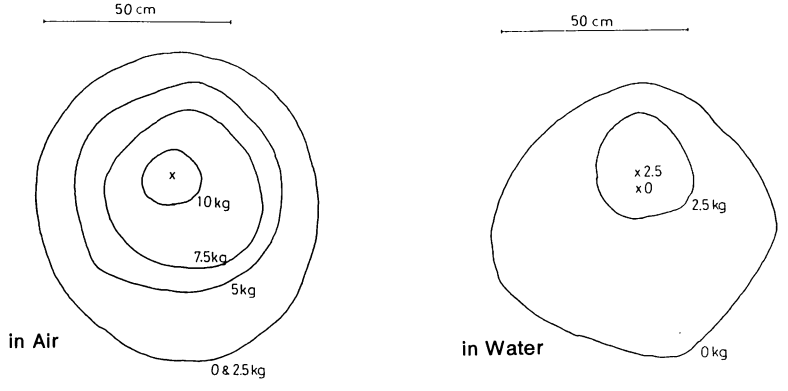

Figure 9 Maximal working capacity against each load in air and in water

Ⅱ. Measurements of working capacity on upper extremity

When subjects work in air, they can perform freely thier upper extremity by maintaining stand upright with their body weight. However, during work in water, they could do only light work against a load pulling them back. From the results of this experiment, we learned the extent to which a results of experiment, it is possible to draw circle against a load of 10㎏ in air, i.e., the maximal working capacity of the upper extremity.

On the other hand, in water, they could not perform drawing more than 2.5㎏.

DISCUSSION

As the values of muscular strength are effected due to harnessing of the body or anxiety during exertion in water, first, we conducted the same tests in air and in water more than 5 times on 5 different days. From these results, after 2 trials of exercise, the values became steady and then we analyzed the data.

Mean values of knee extension in air were 50.46kg, which was 17kg lower than the figures listed in Physical Fitness Standards of Japanese People (3). On the contrary, the upper arm flextion were 33.22kg, 5kg larger than these listed in PFSJP.

As mentioned above, the values of muscular strength are effected by the harnessing of the body. In this experiment, we considered the lower value of knee extension because subjects exerted force without the assistance of the upper body. There was significant difference of knee extension between muscular strength in air and in water. It is an important role of body weight to exert itself maximally in knee extension because this extension, which mainly performs via the quadricep muscle, has a strength two times greater than that of other major muscle groups. However, a lower value in upper arm abduction was not shown. Generally, in terms of muscular strength of the upper extremity, there was not a significant reduction in water (87% to 103% of the maximum in air). From these results, it is relatively easy to construct a training equipment for the upper body in weightlessness environments. However, muscles in the thigh, which make up large part of our body weight, could only perform 70% of the capacity in air, because they require a more stationary positioning of the body.

On the basis of these data, it is not difficult to perform suitable training for maintaining muscular strength and mass in space.

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