Original Article

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The proof of the main function of the muscle biceps brachii to make the elbow joint anti-gravitic extension motion

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ABSTRACT

Objective : "The muscle biceps brachii is the main flexor of the elbow joint" is the common sense in the world.

The object of this study is the proof of the main mover function of the muscle biceps brachii (Biceps) in the anti-gravity elbow extension.

Motion Model : The motion model of this study is the 9 types of the push-up movement from the long-sitting posture on a floor caused by anti-gravity extension motion of the elbow joint.

Subjects : 13 normal young female students were used as the subjects.

Measurement : The maximum voluntary contraction ratio (MVC) of EMG data from 4 muscles (biceps brachii, triceps brachii, anterior deltoid, flexor carpi ulnaris), and the elbow joint angle were measured in the 9 types of the push-up movement.

Results : MVC of the Biceps was higher than the MVC of the triceps brachii in all the 9 types of the push-up movement.

Conclusion : In the push-up movement, both hands were fixed on the floor surface by each subject's body weight. In this situation, the contraction power of the biceps makes the anti-gravity extension motion naturally.

KEY WORDS

muscle biceps brachii, elbow joint, extensor

1. Introduction

Gravity always affects when one's movement or motion is caused on the earth. It is understandable that bipedal locomotion uses the leg muscles, trunk muscles, and especially extensor as anti-gravity muscle. The activity of muscle (the exercise of muscle contraction power) which operates as the source of power in an anti-gravity movement is called anti-gravity muscle activity. One's posture is not always the same. Even if one's motion looks the same, the muscles used for the movement are different according to whether the movement is caused against gravity or gravity helped the movement.

In this study, the authors examine the anti-gravity muscle activity of the arm muscles, especially the flexor. Push motion is done by the movement to extend the distance between a hand and a shoulder (extension motion of the elbow joint). There fore, it has been understood that triceps brachii, which is the extension muscle of the elbow joint, operates as the anti-gravity muscle in hand's push-up motion. In this article, however, authors prove that biceps brachii, which is the main mover of a bend of the elbow joint, can conduct the movement to extend the elbow joint against gravity and that it can cause the motion of pushing a floor with hands.

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Table 1. subjects

age (year)	weight (kg)	height (cm)	SH (cm)	UAL (cm)	FAL (cm)
19.5 ±0.6	50.4 ±5.6	156.2 ±5.4	82.9 ±2.6	26.1 ±1.5	22.2 ±1.2

young female, n=13

SH, sitting height; UAL, upper-arm length; FAL, fore-arm length

The authors have conducted the corroboration experiment to prove that the anti-gravity muscle used when one pushes a floor with one's hands is the biceps brachii, employing hand's push-up motion which lifts up one's hip by pushing a floor with both palms in the long-sitting posture.

2. Methods

1) Subjects

Young normal females were used as the subjects as the Table-1 shows.

2) Methods

The author used the vertical load meter (Kyowa Electronic Instruments Co. LTD, ECG-1010CS1), one set of which has three plates. One plate of the vertical load meter was placed in the front, the other two plates were placed right and left at the back. Then, each subjects sat on the three plates in the long-sitting posture with her posterior side of the both heels on the front plate, her right hip and right hand on the right plate, her left hip and left hand on the left plate, and her rent of the hip corresponding with the joint line of the right and left plates of the vertical load meter.

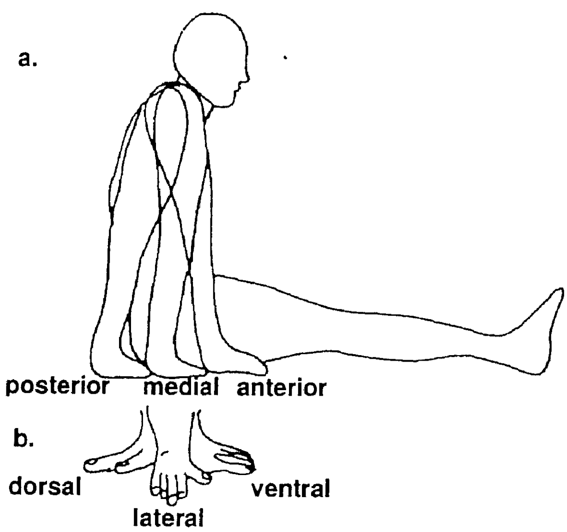


Fig 1. Hand position and fingers direction in push-up motion

Hand positions on the vertical load meter were determined by the central position of the carpal part of the hands. Three hand positions were examined as the Figure-1a shows ; 5 cm from the side of the grator trochanter of the femoris (medial), 5 cm from it and 10 cm forward (anterior), and 5 cm from it and 10 cm backward (posterior). Three hand directions were also adopted with the fingers looking forward (ventral), outside (lateral), and backward (dorsal) as the Figure-1b shows. So, 9 types of hand positions were examined as a whole. (PV, posterior and ventral ; PL, posterior and lateral ; PD, posterior and dorsal ; MV, medial and ventral ; ML, medial and lateral ; MD, medial and dorsal ; AV, anterior and ventral ; AL anterior and lateral ; AD, anterior and dorsal) With the sign of "Start," the subjects started hand's push-up motion with the 9 types of the hand position. The measurement had started one second before the motion began and the motion was measured for 5 seconds. Then, the values measured for 3 seconds after the elbow's full extension were wrapped up.

3) Indication of the Measurement Values

The items of the measurement are the electromyograms from the surface electrode of the anterior deltoid (Deltoid), the biceps brachii (Biceps), the triceps brachii (Triceps), and the flexor carpi ulnaris (FCU) of the right arm measured by the multi-usage telemeter-551 of the Japan Electron Sanei Company. At the same time, loads held by the right and left

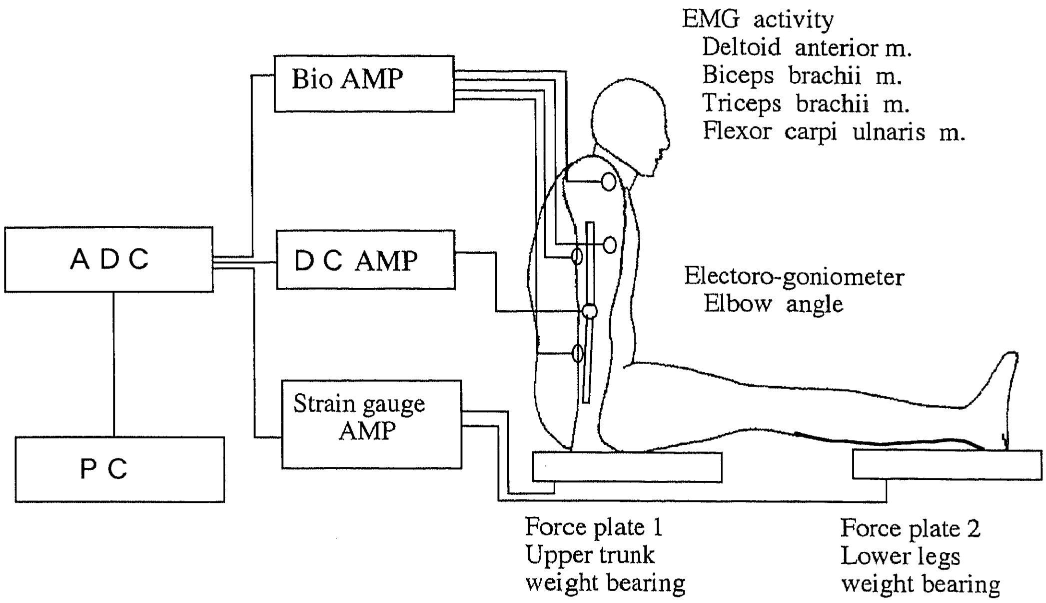


Fig 2. Schematic illustration of experimental set up

legs and hands, and the angle of the right elbow joint were measured. (The electro-gonimeter CP2FB of Anima Company was used.) The measurement values were taken into a computer (Macintosh, 6200) with 100Hz through each measurer (Figer-2).

All the measurement values were shown as the average value of the 3-second hand's push-up motion. The loads held by the right and left legs and hands were calculated by the supporting load rate by the body weight of each subject. The elbow joint angle was shown as the angle of the elbow bend from the full elbow extension level. From the electromyograms of each muscle, the average value of the acting EMG level divided by EMG level at the maximum manual resistance was shown as EMG ratio.

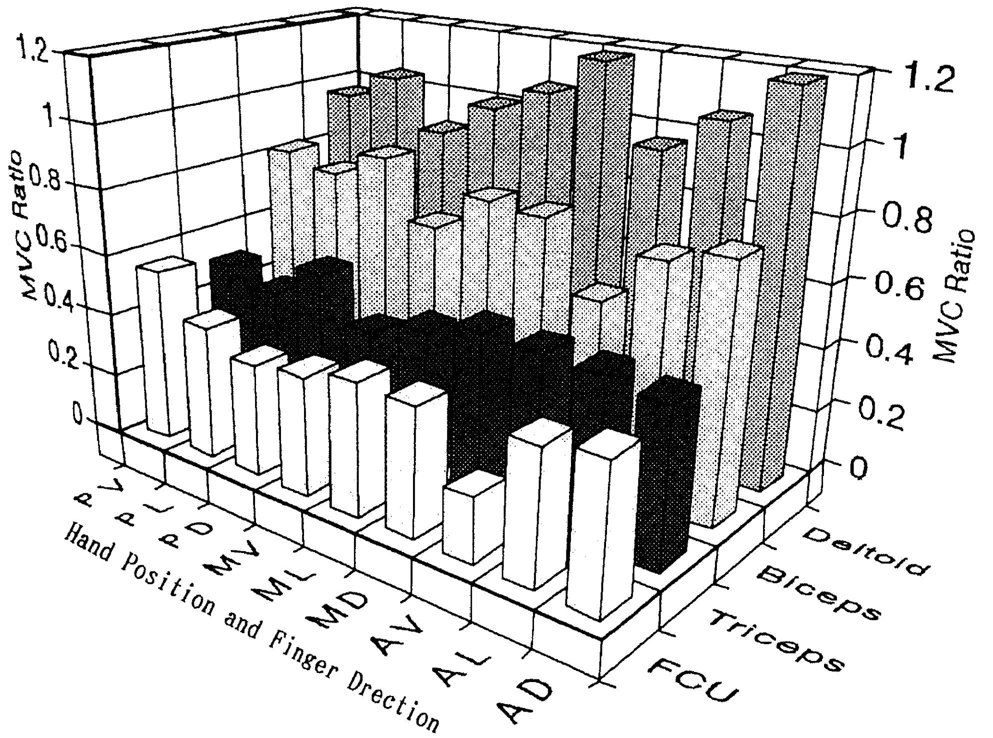
3. Results

The Table-2 shows the load supported by both legs and the right hand, the bent angle of the right elbow joint, and the average values of the EMG ratio of each muscle in the hand's push-up motion with each hand position. The amounts of the loads are shown

Table 2. Summary of subject characteristics in push-up motion

Hand Position	Weight bearing(kg)		ROM(degree)	EMG Ratio			
	Lower legs	Rt hand	Elbow flex	Deltoid	Biceps	Triceps	FCU
PV	17.4	16.5	-1.10	0.96	0.82	0.50	0.55
PL	18.1	16.1	0.18	1.04	0.78	0.45	0.42
PD	18.1	16.1	4.42	0.89	0.86	0.56	0.35
MV	20.4	15.0	4.75	1.00	0.68	0.42	0.37
ML	20.2	15.1	4.47	1.07	0.80	0.47	0.41
MD	20.1	15.2	8.68	1.19	0.79	0.52	0.40
AV	16.2	17.1	5.87	0.96	0.58	0.51	0.20
AL	18.9	15.8	2.38	1.07	0.74	0.50	0.41
AD	19.9	15.2	9.49	1.20	0.79	0.48	0.44

ROM, range of motion; EMG, electromyogram; FUC, flexor carpi ulnaris;
PV, posterior ventral; PL, posterior lateral; PD, posterior dorsal; MV, medial ventral; ML, medial lateral; MD, medial dorsal; AV, anterior ventral;
AL, anterior lateral; AD, anterior dorsal.



MVC Ratio, maximum voluntary contraction ratio; AD, anterior dorsal; AD, anterior lateral; AV, anteriol ventral; MD, medial dorsal; MD, medial lateral; MV, medial ventral; PD, posterior dorsal; PL, posterior lateral; PV; posterior ventral.

Fig 3. Maximum voluntary contraction ratio of four muscles at nine types hand position in push-up motion

by the actual survey value (kg) in the Table-2. The ratio of the load supported by both legs is from 32.1% to 40.5%, and that supported by the right hand is from 29.8% to 32.7%.

The Figure-3 shows the EMG ratio of the 4 muscles in the hand's push-up motion with each hand position. With any hand position, the EMG ratio of the anterior deltoid is the highest (1.2 ~0.89), that of the biceps brachii is the second highest (0.68 ~0.86), that of the triceps brachii is less than 0.6 in any case, and that of the flexor carpi ulnaris is the lowest. Three subjects could not lift their hips with their hands at the PV (posterior and ventral) position.

4. Discussion

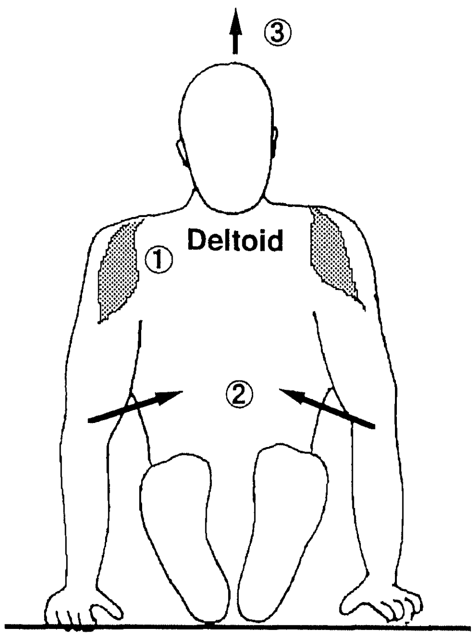
The experiment of hand's push-up motion in long-sitting posture shows the muscular activity in the condition of closed kinetic-chain. Triceps brachii is the flexor of the elbow joint. Therefore, it can be taken for granted that the triceps brachii was active in the hand's push-up motion lifting the hip with the hands pushed to the floor.

The result of this experiment, however, shows that the EMG ratio of the biceps brachii is relatively bigger than that of the triceps brachii in any case. So, the authors study the result, focusing on whether hand's push-up motion by the elbow extension can be caused by the activity of the bicepsbrachii or not. Then the authors mainly study that the biceps brachii, which is originally the flexor of the elbow, provides the muscle contraction power as the power source of the elbow joint extension motion against gravity.

In other words, the authors examine that the biceps brachii operates as anti-gravity muscle in the hand's push-up motion.

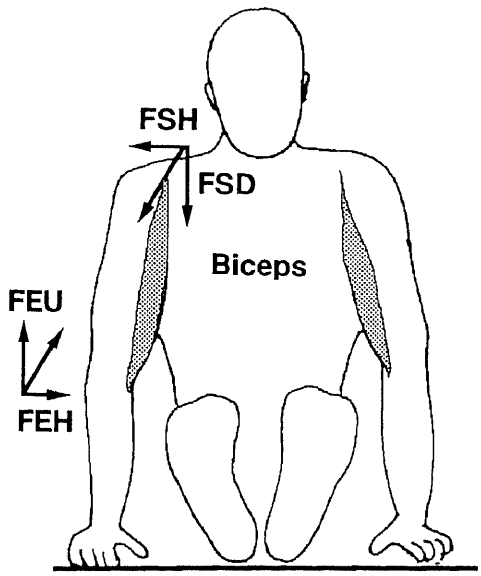
1) The Function of the Anterior Deltoidin the Elbow Joint Extension Motion

First, the authors examine the muscular avtivity of



① contraction power of deltoid muscle make the adduction motion of shoulder joint. ② Shoulder adduction motion make the extension motion of elbow joint. ③ Elbow extension motion make the push-up motion.

Fig 4. Anterior deltoid muscle at shoulder joint and elbow joint in push-up motion



FSH, force vector about the shoulder joint to the horizontal direction; FSD, foce vector about the shoulder joint to the vertical downward direction; FEU, foce vector about the elbow joint to the vertical upward direction; FEH; foce vector about the elbow joint to the horizontal direction.

Fig 5. Antigravity muscle function of biceps brachii in elbow joint and shoulder joint movement

the anterior deltoid. The condition where the elbow heads face outside when the elbows are bent like Figure-4 means that the shoulder joints are in the internal rotation position. The hands are fixed on the floor (the surface of the vertical load meter). The floor, arms, and thorax form the dynamically closed structure. When the shoulder joints take the internal rotation position and the anterior deltoid contracts like ① of the Figure-4, the upper arms are adducted and the elbows move toward inside like ② of the Figure-4, then as a result the hip is lifted from the floor and the hand's push-up motion happens like ③ of the Figure-4. This result shows that the anterior deltoid becomes the power source of the elbow joint extension motion and it functions as anti-gravity muscle.

2) The Functionof the Biceps Brachii to the Elbow Joint

The muscle described in the Figure-4 can be replaced with the biceps brachii muscle.

(1) First, the function of the muscle contraction force vectors to the horizontal direction (FEH in the Fugre-5) and the vertical upward direction (FEU in the Figure-5) of the biceps brachii at the insertion near the forearm is considered. ① The force vector at the elbow to vertical upward direction (FEU) is the power for lifting the hands. However, since a part of the body weight is supported by the hands, there is no chance for the hands to leave the floor. ② The force vector at the elbow to horizontal direction (FEH) is toward inside and it principally functions for elbow bend. There are two types of elbow bend motion. One is the elbow bend motion which happens when a forearm moves and the hands leave the floor. This motion, in which a forearm moves toward the upperarm, however, does not appear now as examined in ①. In the other elbow bend motion, the upperarm moves toward a floor. However, this motion is against joint adduction motion of the upperarm which occurs as the already examined function of the anterior deltoid. So, the effect of the vector-FEH does not show up, either. That is, the elbow bend motions do not seem to be seen in the hand's push-up motion,

and actually they did not appear in the experiment. ③ Then again, the vector horizontally looking inside (FEH in the Figure-5) has to be considered. It is understandable that this vector is the force to pull the proximal part of the forearm toward inside. When the proximal part of the forearm moves toward inside, the elbow joint extends.
That is, the biceps brachii affects the elbow joint extension motion.

(2) Next, what to be considered is the horizontal and vertical vectors of the muscular strength at the biceps brachii muscle's origin of the scapula bone (FSH and FSD in the Figure-5). ① The vector-FHS is the force to pull the scapula bone horizontally toward outside. When the outer-end part of the scapula is pulled toward outside, the scapula slides on the thorax and protraction motion occurs. The scapula protraction motion becomes the outer downward movement of the grenoid fossa of the scapula in the Figure-5. ② The vector-FSD is the force to pull the scapula vertically downward. In this case too, the scapula slides on the thorax and the protraction motion occurs. That is, this vector becomes the power to move the grenoid fossa of the scapula downward. After all, both of the vector-FSD and vector-FHS pull the grenoid fossa of the scapula downward. When the grenoid fossa of the scapula moves downward, the upper part of the body moves relatively upward.

(3) In the Figure-5, the scapula moves relatively downward than the thorax and the thorax moves relatively upward than the scapula. The downward movement of the grenoid fossa of the scapula in the Figure-5 is the same as the movement of hand's push-up motion, which lifts upper part of the body upward with the hands pushing a floor downward. There fore, the biceps brachii at the shoulder joint again functions as anti-gravity muscle and causes the hand's push-up motion.

(4) Moreover, taking it into consideration that a forearm connects to the upperarm through the elbow, the muscular activity of the biceps brachii in the Figure-5 is the same function as the anterior deltoid in the Figure-4 and it functions to extend the elbow joint by adducting the upperarm. Anyway, in the Figure-5, the biceps brachii provides power source for the movement against gravity and functions as anti-gravity muscle.

3) The Function of the Biceps Brachii to the Shoulder Joint

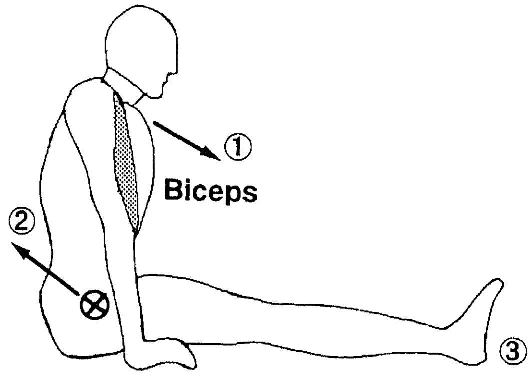
The Figure-6 shows the side view of the hand's push-up motion with the hands anterior, and the biceps brachii is described in it. The authors examine the function of the biceps brchii at the elbow joint extension level when palmar surface is fixed and supporting a part of the body weight. It has already examined that the elbow joint extension level is fixed by the deltoid, biceps brachii, and triceps brachii. In the condition where the elbow extension level is fixed, the load of the upper part of the body added through the elbow and shoulder is supported by the palmar surface. Therefore, the load is relatively bigger at the elbow and the palmar surface than at the upper part of the body. Biceps brachii is the muscle which joins the proximal end of the forearm to the scapula (the upper-end of the body). So, the muscular strength of the biceps brachii affects through the scapula bone the upper part of the body (the scapula part), the load of which is relatively lighter than that of the hands. That is, the muscular strength of the biceps brachii pulls the upper part of the body down-forward. Therefore, the hip at the lower-end of the body is lifted up-backward. Then, the muscular strength of the biceps brachii appears as the function to lift the hip from the floor, and as a result, the hand's push-up motion occurs.

The Figure-6 also shows that in the hand's push-up motion the hands and the heels are connected through the floor and form the dynamically closed structure where the human body continues from the hands to the heels. Therefore, another understanding is possible that the biceps brachii, having its starting point at the propping upper arm, turns the whole body up-forward except the arms. (Only the head is turned down-forward.)

So,in the Figure-6, the function of diarticular muscle of the biceps brachii for the shoulder joint is to lift the upper part of the body keeping through the shoulder joints against gravity, and it is a function as anti-gravity muscle.

4)On the Function of the Biceps Brachii to the Elbow Joint

The Figure-7 is the side view of the hand's push-up



① Contraction power of the biceps brachii pull down-forward the shoulder that is the upper end of the trunk, ② so that the hip at the lower end of the trunk is lifted up-backward, ③ these motion appear on both heels of feet that is a fulcrum of this push-up motion.

Fig 6. Biceps brachii muscle function of hip lift up movement in push-up motion

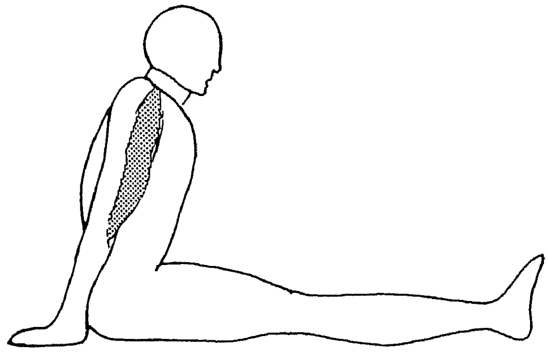


Fig 7. Biceps brachii muscle function of elbow joint extention in push-up motion

motion with the hands at the PD (posterior and dorsal) position. When the hand's push-up motion is done this way, it seems that the subjects lift the pelvis up forward, bending the lower part of the trunk by the contraction of the muscle of abdomen, and keep this position, moving a little forward the upper-end of the the body which is the starting point for lifting the pelvis. Then inevitably, the elbow extension motion by the biceps brachii does not happen. Therefore, in the Figure-5 the biceps brachii pulls forward the proximal end of the forearm and operates as the power source of the elbow extension motion, then the anti-gravity muscular function is caused. As it has already been examined, if the biceps brachii is replaced by the anterior deltoid here, the idea can be valid that the shoulder bend by the deltoid affects the elbow extension and the anti-gravity muscular function of the anterior deltoid also exists.

5) The Difference Caused by the Finger Directions

In the Figure-7, fingers are looking dorsally, so the shoulder joint takes the external rotation position. In the external rotation position of the shoulder joint, the scapula is in the rear of the back. On the other hand, if the fingers are looking ventrally, the shoulder joint takes the internal rotation position. In the internal rotation position of the shoulder joint, the scapula is at the outside of the thorax. Here, the distance between the hand and the grenoid fossa of the scapula is considered. With the hands at the posterior position like the Figure-6, the distance between the hand and the grenoid fossa of the scapulais longer when the shoulder joint takes the internal rotation position than when it takes the external rotation position. Therefore, when the fingers are looking dorsally, the extension of the distance between the hand and the grenoid fossa of the scapula works effectively on the hand's push-up motion. On the other hand, when the fingers are looking ventrally, the extension of the distance between the hand and the grenoid fossa of the scapula can be inadequate for the hand's push-up motion, so in the three cases the hip was not lifted.

5. Conclusion

We have studied the function of the arm flexor as anti-gravity muscle when the anti-gravity muscle is defined as the muscle which provides the muscular strength as the power source for the joint motion to the direction against gravity. The subjects are 13 healthy young women. They do hand's push-up motion to lift the hip from long-sitting posture with the heels put on a floor and the hands pushing the floor. The anti-gravity muscular function of the anterior deltoid and especially biceps brachii at the elbow joint is measured.

1) The anterior deltoid becomes the power source for the elbow extension motion by the adduction and the bend motion of the shoulder, then it functions as anti-gravity muscle.

2) In the posture of this hand's push-up motion, dynamically closed structure is formed between the arms

with the hands fixed on the floor through the thorax, and between the arms and the legs on the floor through the body. So, the biceps brachii becomes the power source of the elbow extension, then it functions as anti-gravity muscle.

3) Through the scapula, the biceps brachii lifts the hip, or the lower-end of the body, then it functions as anti-gravity muscle in the shoulder joint motion, too.

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肘関節の抗重力伸展運動の主動作筋としての上腕二頭筋の働きの実証

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要　旨

上腕二頭筋は肘関節屈曲運動の主動作筋であると言うのは，常識である。しかし，本研究では，肘関節の抗重力伸展運動の主動筋として上腕二頭筋が働くことを実証する。この動作のモデルとしては，長座位で床に両手をついてプッシュアップして臀部を持ち上げる動作を９形設定した。対象は若年健常女性13名である。測定はプッシュアップ動作時の，上腕二頭筋，上腕三頭筋，三角筋前部繊維，尺側手根屈筋の各表面筋電図を測定して筋電位割合（最大随意収縮時の筋電位に対する割合）を求め，同時に肘関節角度を電気角度計で測定し求めた。結果，上腕二頭筋の筋電位割合は，９形全てのプッシュアップ動作で上腕三頭筋の筋電図割合より高かった。手掌が体重で床に固定されるプッシュアップ動作では，前腕付着部で前腕上端を内側に引く上腕二頭筋の収縮力は肘関節を伸展することが，実験的に明示された。