ON THE FORCE MOMENT OF STRETCHING OR FLEXING THE KNEE AND THE HEIGHT OF VERTICAL JUMPING

W. Zefang

Beijing, P. R. China

INTRODUCTION

Many scholars have conducted research on the force moment of stretching or flexing the knee. Many researchers have also studied vertical jumping and discovered many important findings. However, few researchers have studied the interrelation between them. Our aim was to further research the force moment of stretching or flexing knee in different angular velocity conditions and to apply the results to different verticial jumpings to find the relation between them.

METHODOLOGY

Nine male(1.93 ± 0.04 m; 79.0 ± 4.5 kg) and nineteen female(1.81 ± 0.03 m; 60.0 ± 3.9 kg) volleyball players from a provincial team in China were tested for the results of four different vertical jumpings. They were tested in the following conditions: 1) free vertical jumping; 2) vertical jumping with hands on the back; 3) deep-crouching vertical jumping; and 4) static-crouching vertical jumping.

The subjects were tested in the jumping conditions on the KISTLER 9281 force platform and were simultaneously filmed. The test for the force moment of stretching and flexing the knee was made using the CYBEX 350 isokinetic force testing machine. The angular velocity was set 60, 120, 180, 240, and 300°/s. The subjects were tested four times in the different angular velocity conditions. The parameters evaluated were : 1) the result of verticial jumping (H); 2) the maximum force moment value of stretching the knee normalized to body mass (Mmax/BM); 3) the knee angle at the maximum moment of stretching knee (Mmax); 4) the force moment value of stretching knee when the knee angle is 90° normalized to body mass (M90/BM); 5) the force moment value of stretching knee when the knee angle is 120° normalized to body mass (M120/BM); 6) the maximum total work value of stretching the knee normalized to body mass (Wmax/BM); and 7) the maximum average power value of stretching the knee normalized to body mass (P/BM).

RESULTS AND DISCUSSION

Table 1 shows that comparing the four different techniques of vertical jumps, the free jumping leads to the best result, followed by deep-crouching vertical jumping, static-crouching vertical jumping, and the vertical jumping with hands on the back. Using t-tests for statistical evaluation, it was apparent that the vertical jumping with hands on the back produced significantly different results from the three other conditions ($p<0.05$).

Table 1. Results of the vertical jumping parameters.

	H1(m)	H2(m)	H3(m)	H4(m)
Male	0.609±0.067	0.506±0.055	0.604±0.073	0.568±0.061
Female	0.468±0.048	0.406±0.047	0.463±0.053	0.448±0.049

From Table 2 we can see that when the given angular velocity increases, the following parameters decrease: the relative value of the maximum force moment of stretching or flexing the knee, the relative value of the force moment of stretching or flexing the knee when the knee angle is 90° or 120°. As far as each subject is concerned, when the knee angle is certain, the force arm of stretching or flexing knee of stretching or flexing knee muscles is certain. Since the force moment equals the force multiplied by the force arm, we can come to the conclusion that the shrinking force of stretching or flexing muscles decreases when the speed of shrinking increases. The Hill equation shows that when the single muscle shrinks, the force decreases as the shrinking speed increases. As has been shown above, the shrink of stretching or flexing muscles fits the law of a single muscle's shrink.

Table 2. The force moment of stretching (s) or flexing (f) knee parameters.

	0 (°/s)	60 (°/s)	120 (°/s)	180 (°/s)	240 (°/s)	300 (°/s)
Males (s)						
Mmax/BM	4.39±1.02	3.43±0.6	2.87±0.2	2.54±0.2	2.12±0.2	1.09±0.1
Mmax		107.9±5.9	113.9±6.7	118.8±5.5	120.6±6.7	123.7±8.0
M90°/BM		2.72±0.4	1.79±0.2	1.46±0.1	0.99±0.4	0.65±0.3
M120°/BM		3.07±0.7	2.77±0.3	2.45±0.2	2.03±0.2	1.79±0.2
Wmax/BM		3.57±0.5	3.05±0.3	2.55±0.2	2.17±0.2	1.85±0.2
P/BM		2.24±0.4	3.64±0.4	4.54±0.3	5.06±0.5	5.32±0.5
Females (s)						
Mmax/BM	3.07±0.5	2.91±0.4	2.38±0.3	2.06±0.2	1.79±0.2	1.50±0.2
Mmax		113.7±6.4	119.0±5.8	118.1±6.0	124.5±4.6	125.6±5.3
M90°/BM		2.22±0.3	1.62±0.2	1.21±0.2	1.08±0.2	0.65±0.3
M120°/BM		2.74±0.4	2.34±0.3	2.02±0.2	1.75±0.2	1.44±0.2
Wmax/BM		3.18±0.4	2.74±0.3	2.27±0.2	1.93±0.2	1.59±0.2
P/BM		1.96±0.3	3.22±0.4	3.97±0.4	4.45±0.5	4.53±0.5
Males (f)						
Mmax/BM	1.93±0.2	2.08±0.2	1.09±0.2	1.75±0.1	1.46±0.2	1.30±0.1
Mmax		137.8±10.2	131.1±5.9	124.6±3.9	117.7±9.3	116.8±4.3
M90°/BM		1.42±0.2	1.36±0.1	1.24±0.2	1.06±0.2	0.94±0.2
M120°/BM		1.06±0.2	1.71±0.2	1.53±0.2	1.19±0.1	0.95±0.5
Wmax/BM		2.41±0.3	2.15±0.3	1.79±0.2	1.48±0.3	1.26±0.2
P/BM		1.58±0.2	2.54±0.2	3.16±0.3	3.41±0.6	3.64±0.5
Females (f)						
Mmax/BM	1.51±0.2	1.61±0.2	1.49±0.2	1.32±0.2	1.10±0.3	0.98±0.2
Mmax		137.5±8.7	134.9±5.7	126.1±6.2	117.5±7.3	119.2±10.9
M90°/BM		1.51±0.2	1.39±0.2	1.19±0.2	1.00±0.2	0.89±0.2
M120°/BM		1.19±0.2	1.10±0.2	0.96±0.2	0.88±0.2	0.73±0.2
Wmax/BM		1.96±0.4	1.74±0.3	1.45±0.3	1.24±0.2	0.99±0.2
P/BM		1.19±0.2	2.06±0.3	2.54±0.4	2.86±0.5	2.82±0.6

In addition, as the given angular velocity increases, the knee angle increases when the maximum force moment of stretching the knee is produced. The results of flexing the knee are opposite. That is to say when the shrink of stretching or flexing

muscles reaches its maximum force, the shrinking distance increases as the shrinking speed increases. But the disparity is not apparent. The time reaching its maximum force decreases as the shrinking speed increases (Table 3).

Table 3. Time to the maximum force parameters.

	60 (°/s)	120 (°/s)	180 (°/s)	240 (°/s)	300 (°/s)
male(S)	0.63±0.1	0.37±0.2	0.27±0.1	0.21±0.1	0.18±0.1
female(S)	0.73±0.1	0.41±0.1	0.27±0.1	0.23±0.1	0.19±0.1
male(F)	0.54±0.2	0.34±0.1	0.26±0.1	0.21±0.1	0.18±0.1
female(F)	0.55±0.1	0.29±0.1	0.24±0.1	0.22±0.1	0.17±0.1

The relative value of the total work also decreases as the given angular velocity increases. When collecting the data, we required the same movement range of the knee joint. Thus the force moment of stretching or flexing the knee decreases as the given angular velocity increases. The relative value of the average power increases as the given angular velocity increases. As far as each subject is concerned, when the muscle force is certain, the sooner the muscle shrinks, the larger power the muscle produces.

Table 4. Relationship between vertical jump and force moment parameters.

	0(°/s)	60(°/s)	120(°/s)	180(°/s)	240(°/s)	300(°/s)
Females (s)						
Mmax/B	0.560*	0.519*	0.527*	0.552*	0.614**	0.510*
Mmax		-0.072	0.071	-0.324	0.465*	0.110
M90°/BM		0.392	0.426	0.455	0.151	0.379
M120°/BM		0.431	0.506*	0.550*	0.674**	0.533*
Wmax/BM		0.482*	0.563*	0.600**	0.685**	0.674**
P/BM		0.498*	0.507*	0.525*	0.672**	0.648*

* $p<0.05$; ** $p<0.01$

Table 4 shows that for females, in given conditions when the five different angular velocities are certain, the relative value of the maximum force moment of stretching the knee, the relative value of the total work, and the relative value of the average power are in the direct ratio with the results of free jumping. Particularly when angular velocity is 240°/s, they have the closest relationship ($p< 0.05$). The results of the males have the same tendency ($p>0.05$).

CONCLUSIONS

1. When the given angular velocity increases, the following parameters decrease:
a) the relative value of the maximum force moment of stretching or flexing the knee;
b) the relative value of the total work; and c) when the knee angle is 90 or 120° respectively, the relative value of the force moment of stretching or flexing knee.
When the given angular velocity increases, the relative value of average power increases. Also, as the given angular velocity increases, the knee angle increases when the maximum force moment of stretching knee is produced. But the knee angle decreases as the given angular velocity increases when the maximum force moment of flexing knee is produced.

2. Comparing the four different vertical jumpings, the free jumping produced the best result, followed by deep-crouching vertical jumping, static-crouching vertical jumping, and the vertical jumping with hands on the back.
3. For females, in given conditions when the five different angular velocities are cerain, the relative value of the maximum force moment of stretching the knee, the relative value of the total work and the relative value of the average power are in the direct ratio with the results of free jumping. Particularly when angular velocity is 240°/s they have the closest relation. The results of the males have the same tendency.

REFERENCES

Andrews, J. G. (1963). Biomechanical measures of muscle effect. Med Sci Sports Exer 15(3):199-202.

Harris, J. E. (1937). The differential measusement of force and velocity for junior high school girls. Res Quart 8:14-21

Henry, F. (1942). The practice and fatigue effects in the Sargent Test. Res Quart 13:16-29.

Pacheo, B. A. (1957). Improvement in jumping performance due to preliminary exercise. Res Quart 28:55-63.

Pacheo, B. A. (1959). Effectiveness of warm up exercise in junior high school girls. Res Quart 30:202-213.

Sargent, L. W. (1929). Some observations on the Sargent test of neuromuscular efficiency. Am Phys Ed Rev 29: 47-56.

Smith, L. E. (1961). Relationship between explosive leg strength and performance in the vertical jump. Res Quart 32:405-408.