THE ANALYSIS OF ELASTIC STIFFNESS BETWEEN THE SHORT-STRETCH AND LONG-STRETCH DROP JUMPS

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This experiment is to investigate the elastic stiffness of drop jumps (DJ) in order to understand capacity of elastic energy between the short-stretch DJ and long-stretch DJ. Force-platform and electrical goniometer were used to record ground reaction forces and angular displacements of the 11 subjects. The phenomenon of stiffness discovered on the individual muscle of animal also existed in this experiment with the human being implementing the explosive SSC movement, because: 1) The short-range stiffness was significantly larger than eccentric stiffness, 2) Eccentric stiffness was larger than concentric stiffness. When comparing with long-stretch DJ, short-stretch DJ had better capacity of utilizing elastic energy by inducing larger eccentric stiffness and produced larger power by taking a jump of faster concentric average velocity. if the purpose is to induce the capacity of utilizing elastic energy and produce larger power, the short-stretch DJ is recommended.

KEY WORDS: elastic stiffness, elastic energy, concentric velocity

INTRODUCTION: Stiffness is defined asΔforce/Δmuscle length. Cavagna, Citterio & Jacini (1981) and Cavagna & Citterio (1974) studied the muscles of animals, found that when implementing SSC(stretch-shortening-cycle) movement, the Series Elastic Component (SEC) met two opposite requirements.(1) The increase of muscle stiffness will favor to transmit the force and to reduce the coupling time during eccentric phase. 2) The reduction of muscle stiffness will help the release of elastic energy during concentric phase.
From the individual muscle of cat, Rack and Westbury (1974) found the phenomenon of short-range elastic stiffness. When muscle is stretched beyond the short range, the number of cross bridge will be reduced and the force decline, so the stretch amplitude of muscle is a critical factor to determine the strength. They also mentioned that the short-range stretched muscle would make muscle stiffer which was thought to increase the capacity of elastic energy and concentric force (Cavagna, et al. 1981). To understand the characteristics of stiffness and performance between two SSC movements of different stretch amplitude in human being with natural explosive movement, we tried to identify the short-range stiffness, eccentric stiffness, concentric stiffness and the concentric velocity between short-stretch DJ (drop jump) and long-stretch DJ.

METHODS: The movements in this experiment were short-stretch DJ and long-stretch DJ from three heights of 20, 40 and 60cm. There were 11 subjects including jumpers and sprinters in this experiment. Their ages are 23.18±2.64 year, heights are 173.0±4.03cm and weights are 64.31±5.97kg. AMIT force-platform and Penny electrical goniometer were used to record the ground reaction forces and angular displacements. The sampling rate was 1000 HZ and the low pass was 10Hz for ground reaction force and angular signals. After collecting the data, the SPSS software was adopted to calculate the values of the parameters and repeated measures t-test was used to test the difference between short- and long-stretch DJ. The significance level was fixed at 0.05.

RESULTS AND DISCUSSION: 1) The supporting time and stretch amplitude. When implementing the short-stretch DJ, the subjects were told to jump with a knee angle smaller than 75 degrees. and to jump over 85 degrees for the long-stretch DJ. The subjects had to jump as fast and as high as possible. The average of angular displacement of short-stretch DJ of all heights was 70.4±4.9 degree and that of long-stretch DJ was 90.9±4.7 degrees. The supporting time between landing and take-off of short-stretch DJ of all heights was 388±43 ms and 593±43ms was for long-stretch DJ.

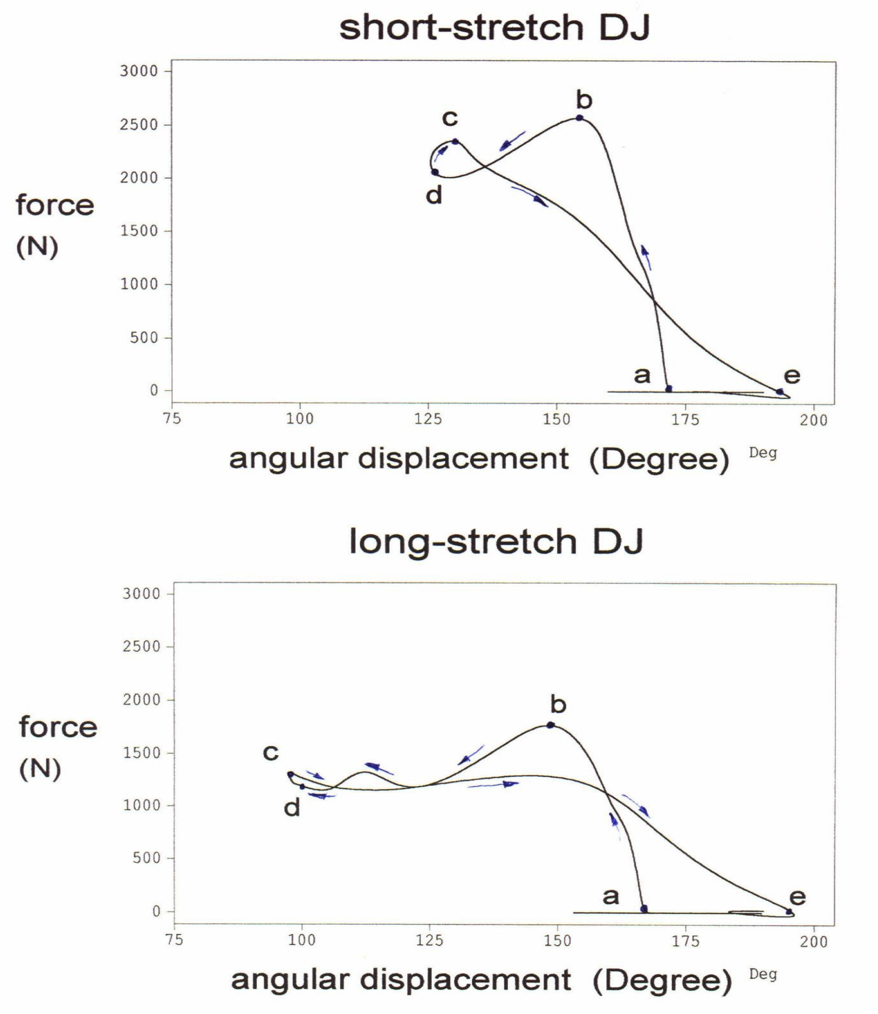

Figure1 - This is a representative figure of force and angular displacement between short-stretch DJ and long-stretch DJ. The abscissa is angular displacement and the ordinate is the ground reaction force of vertical component produced by the DJs. The positive ratio between the points of ab, ac and de are the values of short-range stiffness. eccentric stiffness and concentric stiffness.

Table1 The Comparison of Different Phases of Elastic Stiffness

	Jump height (average±SD unit: N/deg.)		
stiffness	DJ20	DJ40	DJ60
short-range stiffness	58.5±25.4	73.9±23.4	98.8±28.7
eccentric stiffness	35.0±11.0	31.0± 9.3	28.1± 7.9
P value	.035	.000	.000
eccentric stiffness	35.0±11.0	31.0±9.3	28.1±7.9
concentric stiffness	23.5± 5.7	22.8±6.7	21.1±5.6
P value	.000	.000	.000

2) The comparison of elastic stiffness during different phase of SSC movement. The short-range stiffness was significantly larger than the eccentric stiffness at the heights of 20, 40 and 60cm (see Table1). The short-range stiffness reaches the largest stiffness at b as shown in figure1. When muscle is stretched beyond this range and goes through to the end of eccentric phase, the stiffness declines significantly (see Figure1). The phenomenon of short-range stiffness discovered on the individual muscle of animal also existed in this experiment with the human being implementing the explosive SSC movement. When the muscle length is stretched beyond the short-range stiffness, the phenomenon of sarcomere 'give' happens and the number of cross-bridges detachment increases (Flitney & Hirst 1978). As a result, the force and stiffness declined.

On the other hand, the stiffness of eccentric phase was significantly larger than that of concentric phase (see Table1) and the result matched the discovery of Cavagna et al (1981). He pointed out that SSC movement produced stiffer muscle during eccentric phase that could help to transmit force and to reduce the coupling time, and the muscle was compliant that can help to release the elastic energy during concentric phase.

Table2 The Stiffness Difference between Short and Long-Stretch DJ

	Jump method (average±SD unit: N/deg.)		
DJ height	DJ20	DJ40	DJ60
(eccentric stiffness)			
Short-stretch DJ	45.0±8.4	38.3±7.3	34.0±6.3
Long-stretch DJ	26.1±3.0	23.7±3.3	22.2±3.8
P value	.000	.000	.000
(concentric stiffness)			
Short-stretch DJ	28.1±3.4	28.3±5.0	25.0±4.7
Long-stretch DJ	18.9±3.0	17.7±2.5	17.2±3.3
P value	.000	.000	.000

Table3 The Performance between the Short and Long-Stretch DJ

	Jump method (average±SD unit: N/deg.)		
DJ height	DJ20	DJ40	DJ60
(force at the end of pre-stretch unit□B.W.)			
Short-stretch DJ	3.04±0.35	3.09±0.42	2.96±0.40
Long-stretch DJ	2.52±0.28	2.56±0.21	2.55±0.33
P value	.001	.001	.018
(concentric average force unit: BW)			
Short-stretch DJ	2.39±0.12	2.35±0.21	2.30±0.20
Long-stretch DJ	2.02±0.17	1.94±0.08	1.93±0.05
P value	.003	.002	.000
(concentric average velocity unit: deg./s)			
Short-stretch DJ	333.9±46.1	351.6±52.2	345.6±54.7
Long-stretch DJ	298.2±30.4	310.8±33.9	288.5±37.6
P value	.076	.042	.010

3) The comparison of stiffness and performance between the short-stretch and long-stretch DJ. The eccentric stiffness of short-stretch DJ was significantly larger than those of long stretch DJ at the height of 20, 40 and 60cm (see Table2). The stiffer muscle during eccentric phase could favor to transmit force and to reduce coupling time, so the short-stretch DJ should have better capacity of utilizing elastic energy. As for the concentric stiffness, that of long-stretch DJ was significantly smaller than that of short-stretch DJ (see Table2). The compliant muscle during concentric phase could help to release elastic energy. The long-stretch DJ should have released more energy, If it had had enough energy to be released. The fact was that long-stretch DJ did not store higher elastic energy because of lower eccentric stiffness, therefore, did not have much energy to be released.

In this experiment, we found the concentric average velocity of short-stretch DJ was faster than that of long-stretch DJ (see Table3). As we have known, the stiffer short-stretch DJ could help to transmit larger force to the end of eccentric phase (see Table3). The larger force developed at the end of pre-stretch will increase the concentric force. Under the same load, larger concentric force helped to enhance velocity. Under the same mass of subjects, faster concentric average velocity also meant short-stretch DJ could explode larger power.

CONCLUSION: 1, The phenomenon of stiffness happened with ground reaction force in explosive SSC movement produced by human being was the same as that of individual muscle of animal, because 1) Short range stiffness is significantly larger than eccentric stiffness ($P<.05$), 2) Eccentric stiffness is large than concentric stiffness ($P<.05$).
2, Short-stretch DJ had better capacity of utilizing elastic energy, because the eccentric stiffness of short-stretch DJ was larger than that of long-stretch DJ ($P<.05$). Short-stretch DJ produced faster concentric average velocity, therefore, exploded larger power under the same mass ($P<.05$). These facts demonstrated that if the purpose is to induce the capacity of utilizing elastic energy and produce larger power, the short-stretch DJ is recommended.

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