INFLUENCES OF BODY CONFIGURATION ON THE BIOMECHANICAL PROPERTIES OF LEG EXTENSOR MUSCLES IN SQUAT JUMP

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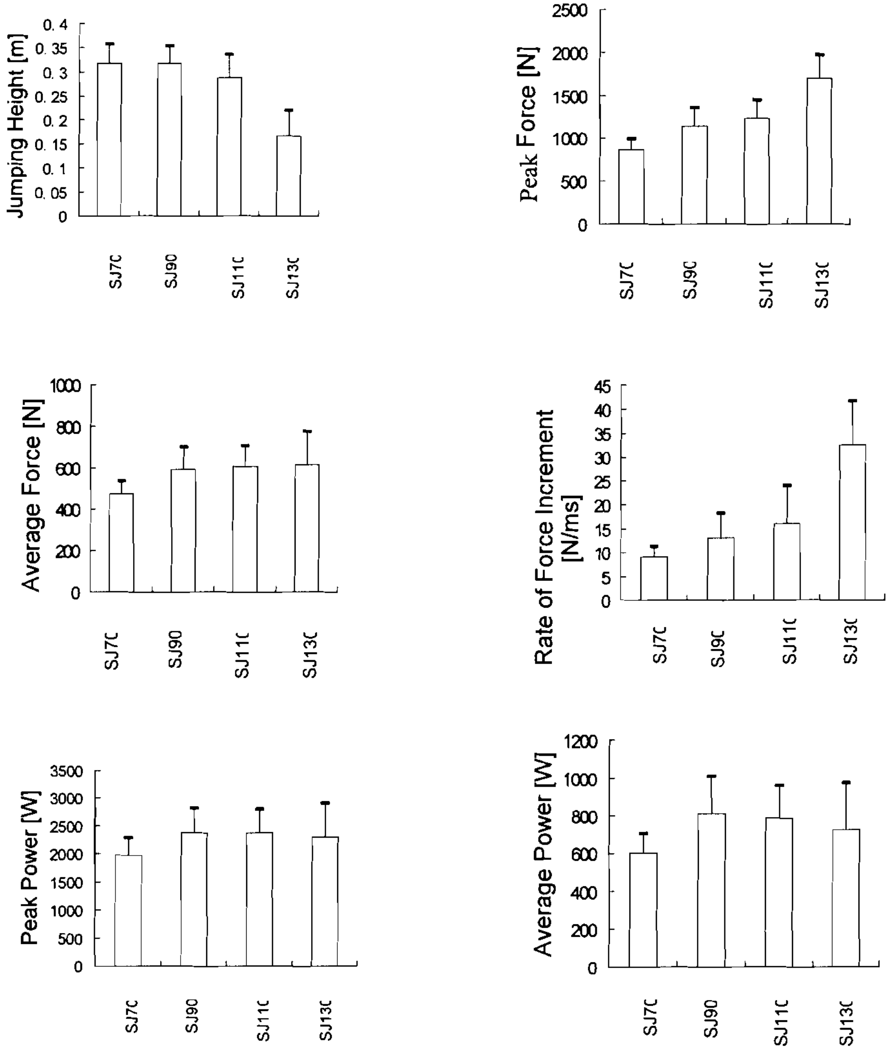
The purpose of this study was to investigate the influences of body configuration on the biomechanical properties of leg extensor muscles in squat jump (SJ) performances. Ground reaction force data were collected during four different SJ tests of SJ70, SJ90, SJ110, and SJ130 (numbers denoted the knee angles) for maximum jump execution of 22 subjects. The results showed that the forces measured on a force platform, and other variables calculated from the force-time data, were strongly associated with the body configuration at push-off. Peak and average forces were greater in wider knee angle conditions, however, optimum power output and jumping height appeared in SJ90. From the data obtained in this study, it seemed that the force production measured with SJ test could not be used simply to assess the level of active state and muscular strength of leg extensors. The reaction force measured on a platform was the vertical component of the muscular strength generated by extensors, which was determined not only by the strength level, but also the joint angles at push-off position.

KEY WORDS: squat jump, body configuration, biomechanical properties

INTRODUCTION: Comparison of squat jump (SJ) and countermovement jump (CMJ) tests on a force platform has been considered as one of the important methods used to study the biomechanical properties of leg extensor muscles for decades (Asmussen et al.,1974, Bosco et al., 1981, Bobbert et al., 1996, Komi et al., 1978). Where SJ tests are concerned, there seems to be no doubt that the configuration of the body, for instance, the knee angle and the hip angle at push-off, should be taken into account in SJ tests. In the literature, however, most studies have focused on differences between SJ and CMJ performances, and few comparisons have been made between SJs starting from different body postures.
Therefore, the purpose of present study was to examine differences of force production measured on the platform, and other biomechanical variables calculated from the force-time data, between different SJ performances. This is an attempt to highlight the importance of body configuration in conducting SJ tests, and to get a better understanding about the influences of body configuration at push-off on the biomechanical properties of leg extensor muscles in SJ performances.

METHODS: Twenty-two normal male subjects were selected for this experiment, aged 25±5 years, with height of 182±5cm, and weight of 75±7 kg. They included eighteen students and four faculty members in the Institute of Sport Science, University of Freiburg, Germany, all of whom agreed to participate in this study. SJs with different push-off positions, denoted by SJ70, SJ90, SJ110, and SJ130 in which the numbers were knee angles (thigh and shank, fully extended=180°) at push-off, were conducted on a force platform (Kistler, sampling frequency 1000Hz). An electrongoniometer was attached to the right knee and connected to an oscilloscope to regulate the knee angles in trials. Subjects were informed to keep their hands on their hips and perform the jumps barefoot. Practice jumps were allowed in order to become familiar with the test requirements. By watching the oscilloscope, subjects were asked to hit the specified knee angle quickly, and to hold the static squat position for less than 2 seconds. Reset was used to get "zero body weight" before jumping. Each subject completed three normal squat jumps (no counter movement) with maximum efforts and required to wait for 1 minute after each trial. The best trial was accepted in force-time data collection, and these data were used to calculate variables such as average force, power output, and jumping height etc., related to the assessment of biomechanical properties of SJ performances.

RESULTS: The means and standard deviations (N=22) of jumping height, peak force, average force, rate of force increment, peak power, average power, and time of extension (push-off to take-off) in four SJ conditions are given in Figure 1.



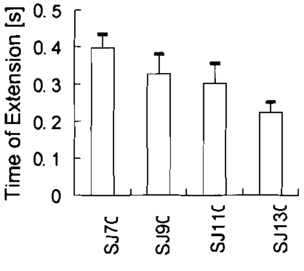


Figure 1 - Comparisons of test results in four SJ conditions.

Statistical differences ($p < .01$) in the rate of force increment, peak force, and time of extension were observed between the SJ conditions. Greater force increment and peak force, but shorter time, were related to wider knee angles. In the results of average forces, statistical differences were found only between SJ70 and other conditions. Jumping heights also showed statistical differences between conditions except the comparison between SJ70 and SJ90, and there jumping height decreased as the knee angle increased. In peak and average power outputs, statistical differences were found between SJ conditions except in comparison between SJ90 and SJ110. The best power output appeared in SJ90, and diminished as the knee angle increased, but SJ70 showed the lowest power output in the four SJ performances.

DISCUSSION: The results of this study demonstrate that the reaction forces measured on a force platform, and other variables such as power output and jumping height calculated from the force-time data in SJ tests, are strongly associated with the body configuration (as indicated by knee angle) at push-off. This result is easy to comprehend and explain, since the joint angles (hip, knee, and ankle) at push-off position determine the initial lengths and shortening extent of leg extensors during a SJ performance, which play an important role in the force exertion and power output of the muscles. It might suggest, therefore, that the body configuration at push-of, can be controlled in SJ tests.

Although the SJ seems to be a simple test, it can be a difficult task to perform under strict experimental situations, since there are some methodological limitations during experiments. It is easy, for instance, to control the knee angle, but is very difficult to control the angles of hip, knee, and ankle at the same time, because the duration of squat position will be too long to make a normal jump. The coordination and effectiveness will be affected as well, in order to adjust the specified three angles. In this case, it maybe practical to control the knee angle first, and then consider other factors where possible.

Concerning the results of present study, linear trends were observed for peak force, rate of force increment, and average force with knee angle (Figure 1). It seems to be inappropriate, however, to conclude that the muscular strength of leg extensors as a whole is greater in SJ with wider knee angle. This can be explained with a biomechanical model of SJ test shown in Figure 2. To simplify, the total vertical reaction force measured on a force platform in SJ test is Fv, and $Fv=F_1+F_3+F_5$, in which F_1, F_3 and F_5 are vertical components of the reaction forces of the plate on hip, knee and ankle respectively. They are determined not only by the muscular strengths of the leg extensors, but also by the joint angles. From anatomical and biomechanical perspective, larger angles (for example, SJ130) present a disadvantage for extensor muscles in production of force, but show some advantage for obtaining greater vertical force components. So the force production measured on the platform, that is Fv, cannot be used directly to assess the active state level and muscular strength of leg extensors without accounting for the influences of joint angles.

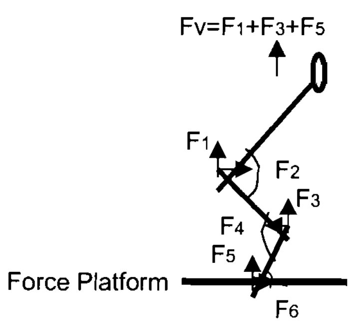


Figure 2 - Biomechanical model of SJ test. Fv is the total vertical reaction force measured on the platform. F_1, F_3 and F_5 are vertical components of the reaction forces of the force platform on hip, knee and ankle respectively in a SJ test.

Time of extension is another important factor, since the take-off velocity that determines the jumping height is determined by the combinations of force and time (impulse-momentum). In the four SJ conditions of this study, it is apparent that the force increased and time decreased with knee angle. The best combination of force and time, in other words, the best power output and jumping height, seemed to occur at SJ90. This result may suggest a basic consideration of knee angle around 90 degree in making an optimum SJ performance. It also has been shown that SJ70 indicated the lowest power output in the four SJ conditions of this study. This may due to the anatomical characteristics of the muscle-tendon complex of the knee and hip angles, as the knee angle is smaller than 90 degree, for instance, the force exertion of the knee extensors on the upward direction would be restricted anatomically and biomechanically.
On the other hand, SJ has been used to provide a comparison base to CMJ for studying the stretching effects of leg extensors (Bosco et al., 1981, Bobbert et al., 1996, Komi et al., 1978). Based on the results of this study, it is recommended that the starting point (indicated by knee angle) of the positive phase of CMJ be the same with the corresponding SJ, in order to make relative accurate and reliable comparisons between CMJ and SJ performances.

CONCLUSION: Body configuration has significant influence on SJ test. It is necessary to control the push-off position and practically to control the knee angle, in order to use SJ test as a means of studying the biomechanical behavior of leg extensor muscles.
Push-off with wider knee angle produces higher vertical force, but sacrifices lower power output and jumping height. The optimum power output and jumping height seems to occur at the condition of SJ90.This provides consideration for doing an optimum SJ performance in exercise and training.
The reaction force measured on a platform is mainly related to the vertical component of the muscular strength generated by extensors. It cannot be used directly to assess the active state level and muscular strength of leg extensors without accounting for the influences of joint angles.

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