FUNCTIONS OF EACH LOWER LIMB SEGMENTS DURING REBOUND JUMPING TAKEOFF

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The objective of this study was to examine the functions of various leg components during takeoff in rebound jumping in terms of the relative impulse and acceleration force of each leg component. The test subjects were 23 male student athletes. The experimental attempts consisted of two sets of five consecutive rebound jumps, where the subjective degree of effort varied among six levels, 100%, 90%, 80%, 60%, 45%, and 30%, which were applied in rand
om order. The focus was on the relative jump height in the derived jump height results. The function of the leg components during rebound jumping was examined, and the attempts involving relative jump heights near 60%, 70%, 80%, 90%, and 100% were analyzed. The results showed that during rebound jumping takeoffs, the foot contributed significantly to achieving the jump height. The foot was responsible for accelerating the upper body in the initial stage of takeoff, whereas that role was taken over by the leg in the middle, and in the second half of the process, the foot once again assumed that role, irrespective of the relative jump height.

KEY WORDS: body segments function, relative impulse, accelerative force.

INTRODUCTION: Rebound jumping is used in sport training to develop explosive power in athletes. Consequently, the mechanism of takeoff in rebound jumping has been studied in terms of kinetic factors such as the joint torque, power, and so on. Although it is important to examine the functions of each body component when takeoff occurs, few studies have covered this subject other than the one conducted by Aoyama et al. (1998). Because the demonstration of power does not always involve maximum effort during actual training or competitions, furthermore, it would also be important to consider the output levels. Therefore, this study also examines the impact of the functions of various leg components during takeoff in a rebound jump for varying subjective degrees of effort. This results can show coaching points in the training.

METHODS: The test subjects were 23 male students (age : 20.8 ± 0.9 years, height : 179.6 ± 6.1 cm, and weight : 82.3 ± 17.0 kg) affiliated with a track and field club. This study was approved by the college of humanities and sciences, Nihon University ethics committee. The experimental attempts consisted of two sets of five consecutive rebound jumps, where the subjective degree of effort varied among six levels, 100%, 90%, 80%, 60%, 45%, and 30%, which were applied in random order. These attempts were captured at a rate of 300 fps by a high-speed camera (GC-P100), which was set up 5 m away from the takeoff point on the right side. Images captured in this manner were used to sample the two-dimensional position coordinates of various body parts (23 points) at a rate of 100 Hz, and the data were converted to the actual length using the position coordinates of calibration markers. The calculated two-dimensional coordinateswere smoothed using the method introduced by Wells and Winter (1980). The optimum cutoff frequencies were between 2 and 9 Hz. The coefficient of Ae et al. (1992) was used for the BSP. Equations (1) to (3), which were introduced by Ae et al. (1985), were used to calculate the relative momentum of joints in the lower regions (on the ground surface side) of the leg that is taking off.

$$GM_{thigh} = M_{(arms+trunk)}V_{hip/knee} + V_{thigh/knee} \quad (1)$$
$$GM_{shank} = M_{(arms+trunk+thigh)}V_{knee/ankle} + M_{shank}V_{shank/ankle} \quad (2)$$
$$GM_{foot} = M_{(arms+trunk+thigh+shank)}V_{ankle} + M_{foot}/V_{foot} \quad (3)$$

where GM represents the relative momentum with respect to the lower regions of the respective body parts, M represents the partial mass, and Vi/j represents the relative velocity of part i with respect to joint j. The acceleration force was calculated by taking the time derivative of the relative momentum. To examine the variation patterns, the results were standardized by 100% using the takeoff time as the point of reference. The relative impulse was calculated from the amount of change in the relative momentum. Positive values of the data indicate a vertically upward orientation, whereas negative values represent a vertically downward orientation.

RESULTS: The relative jump heights of various attempts relative to the maximum jump heights (average value: 35.11 ± 7.13 cm) were as follows. With a degree of effort of 30%, the relative jump height was 57.4 ± 13.7%; at 45%, it was 66.5 ± 11.9%; at 60%, it was 72.2 ± 11.1%; and at 80%, it was 82.1 ± 9.7%, indicating a tendency for the relative jump height to greatly exceed the degree of effort up to 80%. On the other hand, once the degree of effort reached 90%, the relative jump height was 85.8 ± 10.5%, indicating that the relative jump height became smaller than the degree of effort. This study therefore focused on the relative jump height rather than the subjective degree of effort, and the attempts in which a maximum jumping height (100%) was achieved, as well as attempts that correspond to 90±1%, 80±1%, 70±1%, and 60±1%, were selected for observation. Furthermore, the relative jump heights of attempts that were selected in this manner were 89.6±0.8% (n = 8), 79.8±0.8% (n = 14), 70.2±1.0% (n = 14), and 60.3±0.9% (n = 13). An analysis of variance was applied to the two-way positioning of the thigh, shank, and foot at the time that takeoff occurred for the selected attempts that indicated relative jumping height of 60% to 100%, and the results are shown in Table 1. They reveal a significant interaction ($p < 0.001$) between the two factors. A significant effect was also confirmed between various parts of the leg ($p < 0.001$) and the relative jump height. Consequently, the simple main effect was examined, and a significant variance was confirmed at all relative jump heights; further, a significant variance was confirmed for the thigh ($p < 0.05$) and the foot ($p < 0001$). In response to these results, multiple comparisons were conducted, which indicated that the magnitude correlation for attempts with relative jump heights of 100%, 80%, 70%, and 60% was thigh < shank < foot ($p < 0.05$); for attempts with 90%, it was thigh < foot ($p < 0.05$) and shank < foot ($p < 0.05$), where the thigh was 70% < 100% ($p < 0.05$) and the foot was 60% < 90% ($p < 0.05$), 60% < 100% ($p < 0.05$), and 70% < 90% ($p < 0.05$).

Table 1: The results of two-way analysis of variance of relative jump height and the impulse of various sections of the leg.

		relative jump height						
		60%	70%	80%	90%	100%	simple main effect	multiple comparison
impulse	thigh	0.19 ± 0.19	0.12 ± 0.22	0.28 ± 0.23	0.38 ± 0.13	0.35 ± 0.21	***	70<100*
	shank	0.51 ± 0.25	0.64 ± 0.27	0.62 ± 0.32	0.55 ± 0.34	0.71 ± 0.32	NS	
	foot	1.68 ± 0.25	1.75 ± 0.29	1.92 ± 0.31	2.18 ± 0.26	2.22 ± 0.36	***	60<90,100* 70<90,100*
	simple main effect	***	***	***	***	***		
	multiple comparison	thigh<shank<foot*	thigh<shank<foot*	thigh<shank<foot*	thigh,shank<foot*	thigh<shank<foot*		

mean ± s.d. interaction:* ***:p<0.001 **:p<0.01 *:p<0.05

The derived acceleration forces of various sections of the leg are shown in Figure 1. All attempts clearly exhibited similar changes. In the initial takeoff stage, the thigh showed a small negative acceleration force and then a positive acceleration force. In the second half of takeoff, a small negative acceleration force was again indicated. The shank and thigh indicated a similar variance pattern, but the scale of the acceleration force was greater than that of the thigh. The foot indicated a positive acceleration force during takeoff. Such changes indicated a bimodality in which a large value appears in the first half of takeoff, which decreases but then increases again.

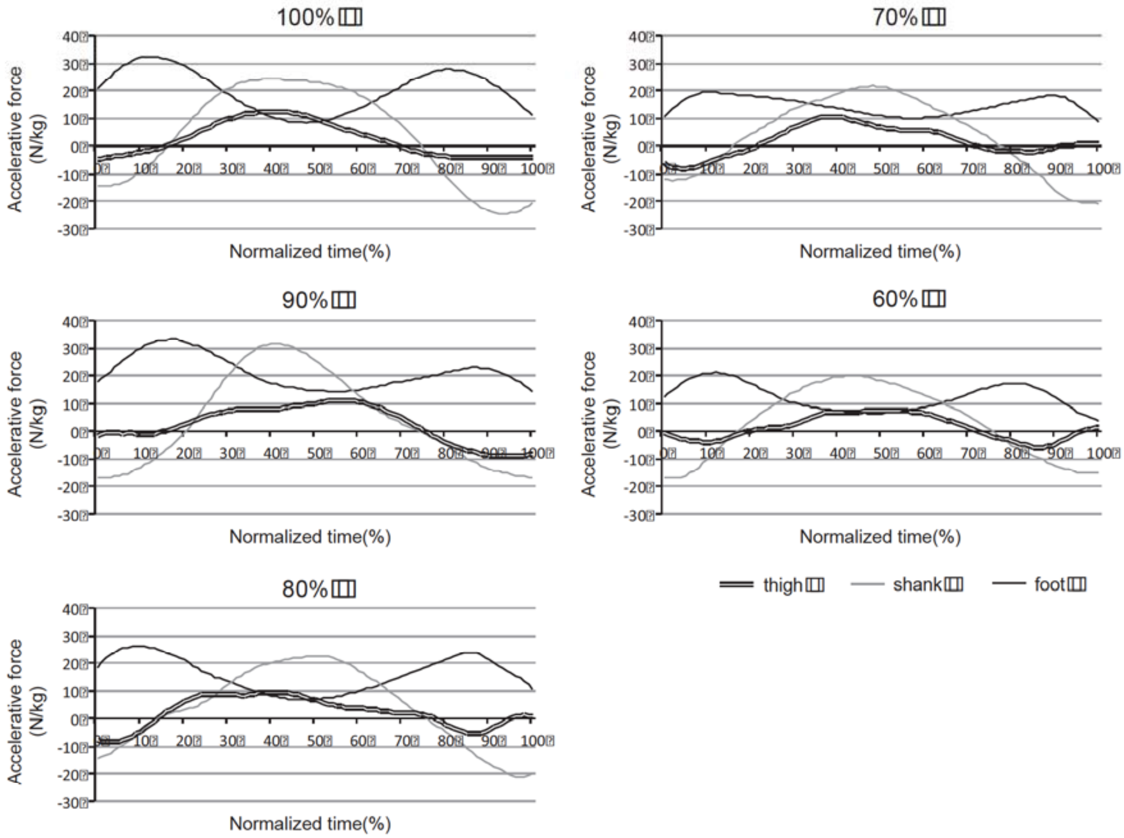

Figure1: The derived acceleration forces of various sections of the leg.

DISCUSSION: The results show that the positive impulse contributed to the achievement of vertical velocity, as it was indicated in each section of the leg in all attempts. The greatest impulse was indicated in the foot. This revealed that regardless of the scale of output, the foot provided the most important contribution to achieving vertical velocity during takeoff in rebound jumps. Consequently, we observed the change in the acceleration force in order to examine the functions of the parts of the leg in more detail. This revealed that the foot exhibited the largest acceleration force before takeoff and in the second half. The foot is considered to provide the function of withstanding the impact from touchdown in the first half of takeoff, whereas in the second half, it is believed to be supporting the body (Aoyama et al., 1998). The ankle exhibits a negative power by an eccentric muscle contraction in the first half of takeoff to absorb the impact (Bobbert et al., 1987a, b). This means that the large acceleration force of the foot is provided by the negative power of the muscle group around the ankle. The acceleration force of the foot also exhibited a significant value in the second half of takeoff, during which vertical velocity is generated. This showed that, similar to the findings on the relative impulse, the foot is playing a major role in achieving vertical velocity. The sole bending moment of the ankle, which directly acts on the foot, rapidly decreased in the second half of takeoff (Mann, 1981), and because the muscle discharge of the gastrocnemius muscle also decreased, it is difficult to believe that the impulse or acceleration force of the foot was generated solely by the actions of the ankle. Van Ingen Schenau et al. (1985) reported that the power generated by the hip and knee joints moved to the ankle owing to the action of the biarticular muscle in jumping movements. This means that the large acceleration force of the ankle is not generated by the action of the ankle alone, but instead by the power generated by the hip and knee joints, which is believed to have been transferred to the ankle owing to the action of the biarticular muscle. This is supported by the fact that the peak of the acceleration force of various parts of the leg during the second half of takeoff occurs in the sequence of thigh–shank–foot. Furthermore, the output control during rebound jumps can be considered to be generated by the same output mechanism. The foot, thigh, and shank are considered to be in a complementary relationship because the acceleration forces of the thigh and shank increase in the middle of takeoff, whereas that of the foot declines. Therefore, The foot movement is important coaching point in the rebound jump training. In addition, the result of this study was the basic knowledge to coach a takeoff technique of the other jumps movement.

CONCLUSION: The objective of this study was to examine the functions of various leg components during takeoff in rebound jumping in terms of the relative impulse and acceleration force of each leg component. It was found that a positive impulse contributed to the achievement of vertical velocity because it appeared in each section of the leg in all attempts. The greatest impulse was exhibited by the foot. This revealed that regardless of the scale of the output, the foot provided the most important contribution to achieving vertical velocity during takeoff in rebound jumps. Consequently, the foot was revealed to be withstanding the impact from touchdown in the first half of takeoff, whereas in the second half, it is believed to be playing a significant role in supporting the body to achieve vertical velocity.

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