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Relationships between Whole Body Reaction Time and the Motion-silent Period and the Action Period in Jump

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Abstract. [Purpose] We divided the jump action into a resting phase and a motion execution phase, so that we could shed light on each phase's relationship with the whole body reaction time in jump. [Subjects and Methods] Whole body reaction of young subjects in their late teens was recorded with a high-speed video camera to identify moving reaction time. [Results] The results revealed a high correlation between jumping reaction time and the light stimulus to movement initiation, and the movement initiation to feet-off. Individual variation existed in neural processing velocity of movement preparation and execution, and the processing velocity was shown to reflect the whole body reaction time in jumping. [Conclusion] The outcome suggests that improvement of body performance can be achieved not only by muscle stretch and elastic energy recruitment training but also by faster neural processing.
Key words: Jump, Movement preparation, Movement execution

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INTRODUCTION

Agility may be characterized by measuring the time from an external stimulus given to a subject, such as light or sound, to the response of his/her body. Whole body reaction time in jump is generally used as an index of agility in sports science in Japan. In a motor task from a light stimulus to the feet-off act, a two-fold processing is involved: information processing in the brain needed to perform the motion, and muscle contraction according to the command received by the peripheral skeletal muscles. This processing sequence is complex and much of it awaits elucidation. Movement preparation in the brain is mostly done in the frontal lobe[1–8)]. At this time the activity of the primary motor cortex consists of two components, one responsible for the preparation of movement and one for the execution of it[9)]. In the movement execution period, transmission of both muscle contraction and the resultant physical energy is required.

In this agility study, we divided the jump action into a resting phase and a motion execution phase, so that we could shed light on each phase's relationship with the whole body reaction time.

SUBJECTS AND METHODS

Sixteen healthy youths (11 men and 5 women; mean age 18.4 ± 0.5 (SD) years old; height 166.8 ± 8.2 cm; body weight 59.2 ± 8.8 kg; and BMI 21.2 ± 2.0) participated in this study.

The subjects were asked to jump vertically as quickly as possible when a red light placed 2 m ahead of them was turned on. The time from light stimulus to both feet aloft was measured (Tkk-1264b, Takei, Japan) and recorded once using a high-speed video camera at a frame rate of 1,000 Hz (Memrecam GX-1, NAC Inc. Japan). Subjects were allowed to practice as much as they wanted before the jump for recording. All were satisfied after four or five trial jumps. The time of the period of motion execution was determined from the recorded images. We also calculated the time from the light stimulus to moving and the time from the start of moving to feet-off. The results were expressed as mean ± standard deviation. We investigated the correlations between the jump reaction time and the time from the light stimulus to moving, and the time from moving to feet-off. We also examined the correlation between BMI and jump reaction time. In the statistical analysis, Spearman's rank correlation coefficients were calculated, and values less than 5% were considered significant.

The significance, purposes, procedures of this study were explained to the subjects, and they all gave their informed consent. The experiments were carried out in accordance with the principles of the Helsinki Declaration.

RESULTS

The mean jump reaction time was 294 ± 44 msec, the mean time from light stimulus to the start of moving was 179 ± 34 msec, and the mean time from just moving to feet-off was 115 ± 25 msec.

The relationship between jump reaction time and the time from the light stimulus to moving was very highly correlated ($r=0.852$, $p<0.000$), and that between the jump reaction time and the time from moving to feet-off was significantly correlated ($r=0.646$, $p=0.007$). No noticeable relationships were found between BMI and the time from light stimulus to moving, or between BMI and the time from just moving to feet-off.

DISCUSSION

In this study we found very high correlations between jump reaction time and the time from the light stimulus to moving, and the time from moving to feet-off in terms of Spearman rank correlation coefficients. In particular, the correlation coefficient between the jump reaction time and the time from the light stimulus to moving was 0.852, which means the two were statistically, very highly correlated. This result suggests that the motion-silent period or action period is proportional to the speed of jumping, that is, the shorter the motion-silent period or action period, the greater the speed of jumping.

The average range of jump reaction times among Japanese youths aged 18 to 19 years old is 340–420 msec[10], which compares with the much smaller range of 294 ± 44 msec that the subjects showed in this study. The average range of onset times of initial reaction among Japanese of the same age group is 190–220 msec[10], and the subjects in our study showed a slightly shorter average. Although they were allowed as much practice as they wanted beforehand, all the subjects were ready within five trials. Therefore, we consider the pre-recording exercise had little effect on the outcome.

From the light stimulus to feet-off, there exist two phases: the movement preparation phase from the stimulus to motor command in the brain, or motion-silent period, and the subsequent motion execution phase. It has been documented that there is a processing delay in the brain due to the complexity of motor tasks[11]. Because the conduction velocity in the nerves is almost constant, individual motor execution ability determines the time of movement reaction. Movement preparation in the brain requires a perceptual set and a motor set. The efficiency of the perception process, signal perception and detection, can be improved by increasing selective attention and the degree of arousal. The motor set, on the other hand, is the process which governs the planning and overall configuration of the movement to maximize the ultimate motor output. Readiness potential is believed to reflect the movement preparation and the intentions of the movement[1, 3, 6]. Also relevant here is negative variation, which is contingent upon external stimuli (hence contingent negative variation, or CNV) and is divided into motor and non-motor components[7, 8]. The non-motor component is involved in the motor set[4, 5].

Here, we must also consider the MRCP, movement-related cortical potential, which is detected at the scalp 1 or 2 seconds prior to voluntary work, and reflects the progressive negative slow potential variation[1, 2]. The MRCP has been divided into nine components[1, 6, 12], and in athletes a reduction is known to occur in the latency of the bereitschaftspotential (BP) and negative slope (NS') within the potential[13]. The BP reflects the readiness for voluntary movement in the supplementary motor area, and the NS' reflects the readiness of the motor cortex specific to the movement[14].

We believe that in the subjects of this study, individual differences possibly arose in the process of movement preparation. We suggest that individual differences in the information processing ability for the movement probably reflected the jump reaction time of subjects in this study.

In the movement from the start of an action to feet-off, muscle stretch reflex and muscle elastic energy is involved. Reflex latency is approximately equal to the sum of the conduction lengths of time in both the central and peripheral nervous systems. In muscles in the lower extremities, the latency of the stretch reflex is 25–35 msec. In faster athletes, the conduction velocity is greater, resulting in a latency that is shorter by a few msec[15, 16]. Athletes have in fact been described in terms of MNCV, or motor nerve conduction velocity[15–21], and individual differences are always present. It is highly notable that the individual differences among athletes is described by electro-mechanical delay (EMD), which is the duration from the beginning of the reflexive muscle activity to the actual rise in the mechanical tension. The EMD depends on individual muscle conduction velocity, which in turn accounts for the individual differences. Improvement of individual physical performance, among athletes and non-athletes alike, may be made through what is called the stretch-shortening cycle exercise, an important factor involving muscle elastic energy and stretch reflex[22].

There were unequivocally high correlations in this study between the jump reaction time and the interval from the light stimulus to moving, and between the jump reaction time and the time from just moving to feet-off. From these, individual differences were revealed in the processing velocity of neural commands for movement preparation and movement execution, and individual processing velocity reflected the jump reaction time. This outcome suggests that improvement of physical performance is not achieved just by the kind of training performed to shorten motion reaction time using muscle stretch reflex and elastic energy, but is also enhanced by greater speed in the information processing velocity in the brain.

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