The Vertical Reaction Force During the Sudden Releasing Movement (Archery Shooting)

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Abstract

The variation of the vertical reaction force during the sudden releasing movement (archery shooting) of the upper limb were observed in the four subjects. They were asked to respond to the clicker signals by shooting an arrow precisely as soon as possible. The movements were filmed at 200 frames/sec with high speed camera to analyze a motion of the hand and trunk before and after the release. The most consistent variation in the vertical reaction forces were obtained in the world top archer, without the vertical fractuation of the center of the gravity observed by the film analysis. This variation were divided into two phases that the first phase appeared just after the releases of 10–20 msec in right foot and the second phase appeared 50–60 msec in both feet. The former positive force were explained by the simple free body diagram of the archer.

KEY WORDS : *Vertical reaction force, High speed camera analysis, Shooting movement*

Introduction

The interaction between exciting and inhibition during the voluntary movement was seemed to be a major role in the mechanisms of motor coordination (Gatev, 1972). The inhibitory phenomenon changing from the preparatory phase to the acting phase was considered to be particularly important in the skilled movement (Yabe, 1976). In the movement of shooting an arrow, we observed a electromyographic silent period (SP) prior to release in two world-class archers (Nishizono, Nakagawa, Suda and Saito, 1984) and concluded that the SP in deltoid muscle was closely related to the skilled movement (Nishizono and Kato, 1985).

To get a high performance in archery shooting, a static, stereotyped movement and a highly reproducible release has been required.

The most common force acting on the body is the ground reaction force which acts on foot during standing and it serves as the one of the primary component of evaluation in the stabilities of posture.

The purposes of the present study were to examine the ground reaction force which

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acted on the foot during an archery shooting and to clarify the biomechanical necessities to keep the stabilities of the releasing movement.

Method

The experiments were performed on 4 males, which were divided into the three skill-levels, the world-class(1), the national-class(2) and the university-class(1) archers. Each subject stood on the two platforms which made it possible to measure the vertical forces. The 3 strain gages transducer were attached in each platform. The subjects were asked to stand on a point 8 m from the target.

The movement leading up to the release of the string with arrow is almost the same in each subject, as holding the tension in full drawing, sighting a target, clicking a clicker and releasing a string, successivly. Each subject shot 30 arrows with 15-20 sec intervals.

A strain gage transducer was attached to the bow for measuring a bow strain and the moment of the releasing. Electrical signal was also detected when the subject clicked a small metal plate on the side of the bow.

The forces data were stored on magnetic tape and analyzed the total vertical forces by means of the mini-computer. The location of the center of the pressure (anterior-posterior and medial-lateral directions) was determined by the relative vertical forces seen at each triangle corner transducers.

The movements were filmed at 200 frames/sec with a 16 mm high speed camera (NAC, 1P) to analyze a motion of the hand and trank before and after the release.

Results

The total vertical reaction forces in each foot (VL, VR) and both feet (VL+VR) were showed the characteristic pattens in the world-class archer (Fig. 1). In the VL (the vertical reaction force of the left foot), a rapid fall was observed after 10-20 ms at the moment of the release (▼), and after 50-60 ms a rapid increase was observed. In the VR (the vertical reaction force of the right foot), the increase of forces were divided into the two phases. The first was at the moment of the release and the second was after 50-60 ms at the release. The second rise was coincident with the left and right foot. The peak-to-peak force values of the both feet (VL+VR) were 24 % of the body weight. The reproducibility of force pattern were high with three trials.

In the university-class archer (fig. 2), almost the same patterns were observed. The peak-to-peak force values of the both foot (VL+VR) were 10 % of the body weight. These sudden changes in vertical reaction forces were involved in the releasing movement.

However, in the world-class archer, the decreasing forces of VL+VR were steeper

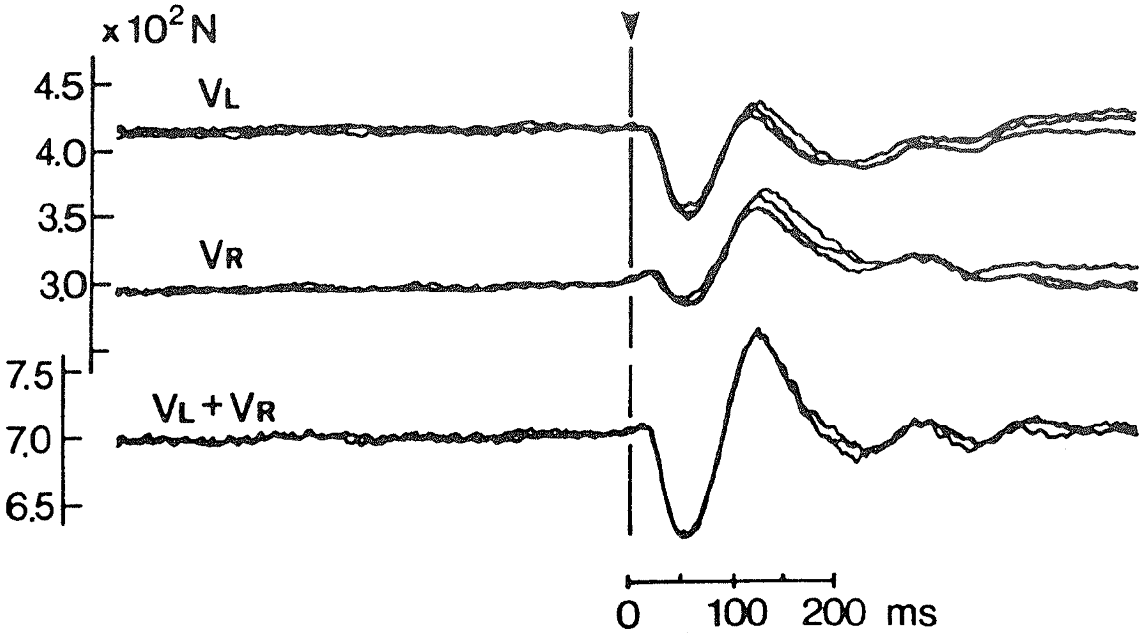

Fig. 1. The vertical reaction forces at the releasing movement (▼) in the world-class archer (overlappted in 3 trials). Upper three traces show the total forces in left foot. Middle three traces show the total forces in right foot. Lower three traces show the total forces in both feet.

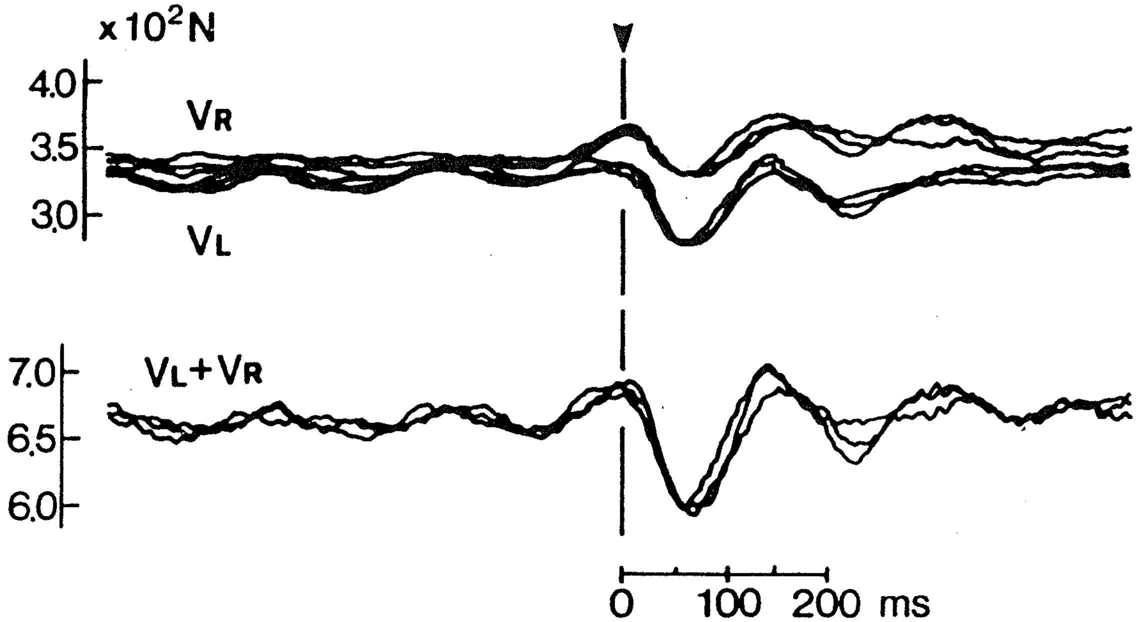

Fig. 2. The vertical reaction forces at the releasing movement (▼) in the university-class archer (overlapped in 3 trials). Upper three traces show the total forces in right foot. Middle three traces show the total forces in left foot. Lower three traces show the total forces in both feet.

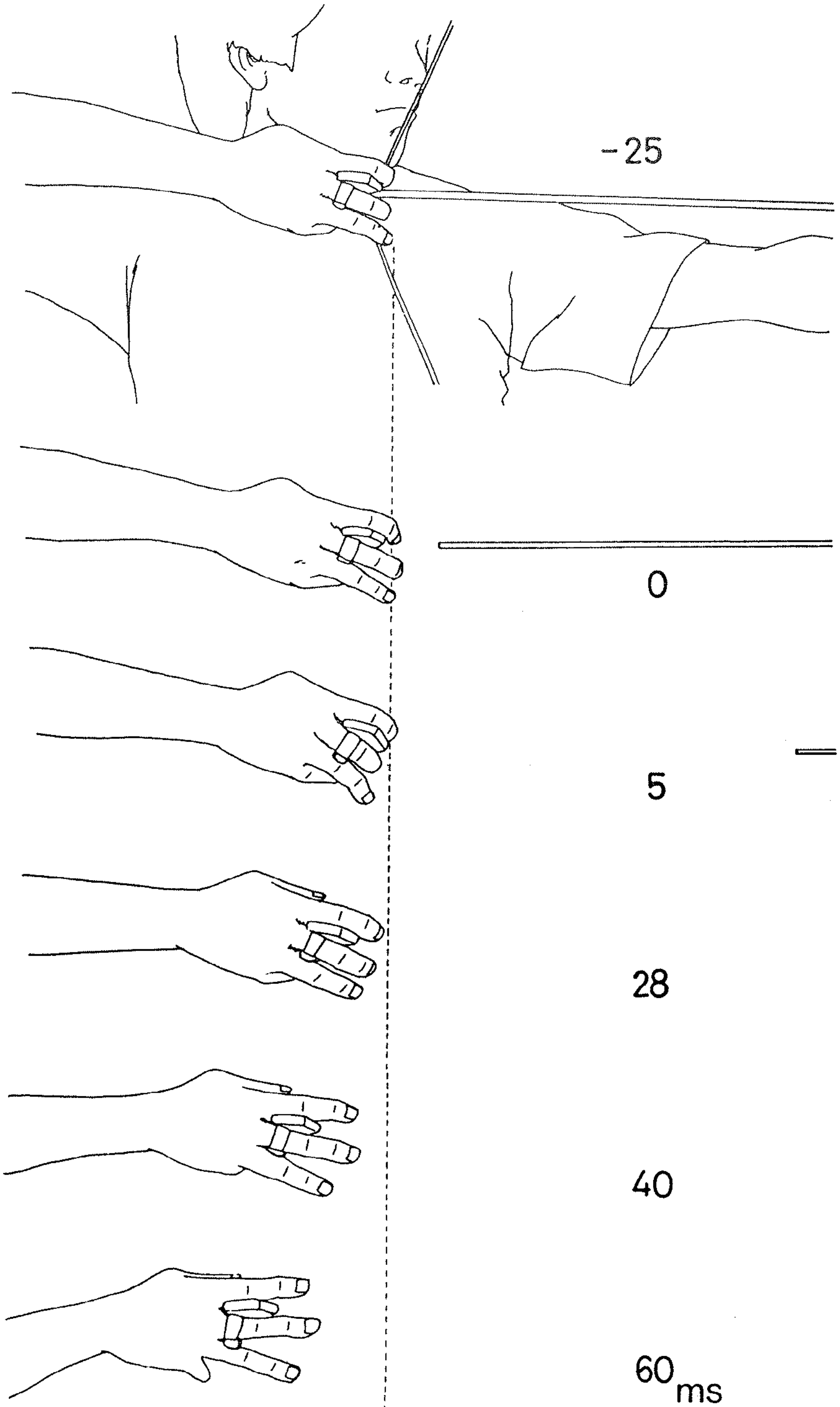

Fig. 3. Succesive high speed picture (200 frame/sec) of the shooting an arrow in the university-class archer. The 0 msec means at the moment of releasing.

than the university-class archer. In the university-class archer, the base lines at the full draw (before the release) were fluctuated with low frequency and the reproducibility were less in three trials.

In the film analysis, the changes of the center of gravity of the body and the arm were not detected. The figure 3 showed the upper limb movement in the medial-lateral directions.

Discussion

To explain the some factors determining the first phase of vertical reaction force, the following theoretical model was proposed by the modification of Shibukawa(1969)'s model.

In the full draw: $FR=FL$

At the moment of the release: $FR=0$

The balance of horizontal direction was defined by

$$-FL+HR+HL=0 \qquad (1)$$

The balance of vertical direction was defined by

$$-W-B+VR+VL=0 \qquad (2)$$

The balance of forces around right foot momentum was defined by

$$h\ FL-(Wd/2)-2dB+dVL=0 \qquad (3)$$

Where:

FL is the pushing force from the bow. FR is the drawing force from the string. HR is the horizontal ground reaction force in right foot. HL is the horizontal ground reaction force in left foot. VR is the vertical ground reaction force in right foot. VL is the vertical ground reaction force in left foot. W is the weight of body. B is the weight of bow. d is the stance length. h is the height of pushing arm from the ground.

From equation (1), (2), (3)

$$VR=(W/2)+(FLh/d)-B \qquad (4)$$

$$VL=(W/2)-(FLh/d)+2B \qquad (5)$$

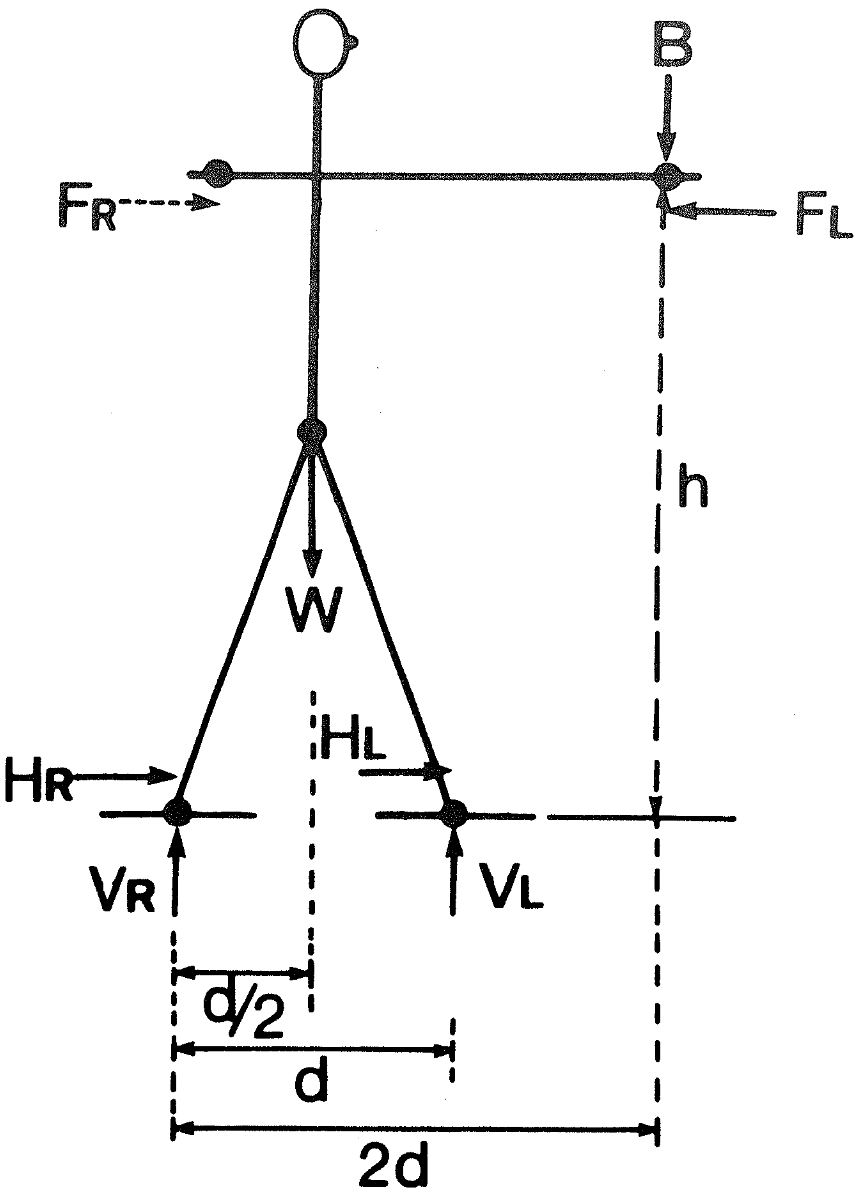

Fig. 4. Schematic diagram of acting on the body during shooting movement.

At the moment of release in right foot, the force of FL h/d were added to the half of the body weight and in left foot the force of FL h/d were subtracted from the half of the body weight. In the equation (4), (5), the weight of bow acts on the compensating role. For the purpose of explaining the first sudden increase in right ground reaction force, it is possible to clarify the factors within some limitations.

The location of the center of pressure of the ground reaction vecter was converged on a small area among subjects, and the medial-lateral changes of center of pressure were almost the same among the subjects.

The inhibitory and exciting activities of upper extremities muscle were reported at the releasing movement (Nishizono and Kato, 1987). In the present study, the vertical reaction force of the external forces were detected in two phases of all subjects. It was assumed that the sudden vertical decreased forces were related to the a switching activities in some upper extremities muscles. The trainned archer, paticularly in the world-class archer, showed the high levels of force in phase 1. The mechanism of this force at the moment of release was considered the compensating action consering the motor preprograming. The existence of postural activity prior to and during a movement has been established in man (Belenkii et al., 1967) and in animal (Ioffe and Andreye, 1969, In Bouisset, 1981). In the movement of shooting an arrow, it was considered that for minimizing the disturbance of the balance the central motor program should concern not only in the muscle involved in the movement itself, but also those which are involved in the postual program.

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上肢による急速な負荷開放動作（弓射動作）時の鉛直床反力の変動

西　薗　秀　嗣

ヒトの随意運動において興奮と抑制の相互関係は，motor coordinationの機構を探るのに重要な意味を持つ。特に動作の切り替わる際に観察される筋活動の抑制現象は，運動技術の獲得に関すると考えられる。本研究では，弓射動作について，身体から受ける力で代表的な鉛直反力を計測すると共に，16mm フィルムによる高速度撮影，分析を試み，姿勢とりわけ上肢の安定性からみた身体運動学的必要性について検討を加えた。被験者は，4名で洋弓について国際的選手1名，日本代表選手2名，大学レベル選手1名であった。フィルム分析から，いずれの被検者にも，上肢の左右方向への移動は認められたが，体幹の上下方向への重心の変動は検出されなかった。しかし，clicker刺激後，弦の急速開放(release)に伴い，鉛直床反力に変化が認められた。特に国際的選手において，150 Nの変動が認められた。この急速な変動は，2成分に分けられた。第1は右足について，release後10-20 msecに，第2は両足での，release後50-60 msecに認められた変動である。前者の現象を説明するモデルを作成し，(FLh/d) -B の力が作用すると考えた。この力は，あらかじめpreprogramされた一連の筋活動によって生じ，抑制現象の後，発現したものと考えられた。

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