BIOMECHANICAL ANALYSIS ON DYNAMIC PULLING SKILL FOR ELITE INDOOR TUG OF WAR ATHLETES

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In order to describe the pulling skill for the elite athletes of indoor Tug of War, the purpose of this study was to determine biomechanical profiles in dynamic pulling exercises. Kanazawa Rescue team of the gold medal record for the 2004 World Indoor TOW Championships participated in this study (N = 20). Our data revealed that the elite tug of war athletes could produce 1041.6 N in dynamic pull, i.e., 149.0% of the weight with the load cell method. According to three-dimensional video analysis procedures with the direct linear transformation analysis (DLT) method, it was cleared that the ankle joint of lower leg was rotating at toe off with the pigeon toe position to outsidewards during pushing the floor. Therefore, it is concluded that the lower limb link system involving COM would be of the most sophisticated skill for the elite indoor TOW athletes.

KEY WORDS: Tug of War, pulling skill, top athletes, DLT

INTRODUCTION: Although tug of war is now a well organized international amateur team sport governed by the Tug of War International Federation (TWIF) and enjoyed by thousands of athletes, little study exists focused on the indoor and the outdoor tug of war sport. Pulling backward exercises in TOW contest can be divided into three phases, namely "drop", "hold" and "drive" phase. It is considered that drive phase is described that exerting pulling force with backward walking and drawing opponent into own territory. This phase is mostly dynamic pulling force exertion. While pulling activity has been focus of much static force exertions, little data exist which describes the dynamic pulling force exertion. Therefore, the purpose of this study was to determine biomechanical profiles in dynamic pulling exercises, to describe the pulling skill for elite indoor tug of war athletes.

METHODS: The team that holds the gold medal record for the World Indoor Tug of war (TOW) Championships 2004 participated in this study (Table1). The force data during the drive phase were collected from the twenty subjects. Kinematic data for three of the 20 pullers during drive phase were obtained. Each subject wore TOW shoes (TOR107, Asics, Japan) and was required to perform a static two handed (TH) pull at his maximal effort in order to determine the loads during drive phase, which were 70% of static maximal loads (Table2). Each subject performed TH pull in the drive phase at his maximal effort (Photo1). Subjects were instructed to pull for 5 seconds. The setting of pulling height was 60cm which was considered the approximate height in a game of TOW. All trials were performed on the indoor TOW lane with official rope against the Tugging machine (Photo2) that allowed for adjustments in levels of load and provided the horizontal resistance (TUGMAN, Showa Electric Wire & Cable Co., LTD, Japan). The load cell (TCLP-200KA, Tokyo Sokki Kenkyujo, Co., LTD, Japan), containing a strain gauge force transducer was set between the rope and the tugging machine, measured the force applied. The forces amplified by the Strain amplifier (6M46, San-ei Instrument Co., LTD, Japan) lead into the computer (VAIO PCG-GRX90/P, SONY, Japan) using the software (Wad system ISF-6E, DKH, Japan) which converts analog data into digital data and collects time series force displacement data. The three digital video cameras operating at 30 frames per second were placed in three different directions to film movement of subjects during trials. The three-dimensional motion analysis system (Frame-DIAS for Windows, DKH, Japan) was used to digitize the anatomical landmarks of the body. The direct linear transformation (DLT) method of motion analysis for 3-D space reconstruction from 2-D images was used.

RESULTS AND DISCUSION: The mean maximal pulling forces was 1041.6 ± 123.9 N ranged from 792.3 to 1240.7 N (Table3). The percentage of dynamic pulling force in static maximal pulling force was 75.5 ± 14.4%. The mean maximal static and dynamic pulling force divided by the weight were 201.8 ± 38.2% and 149.0 ± 23.1% respectively. The dynamic pulling forces expressed as a percentage of weight was ranged from 106.4 to 182.5%. Our data revealed that the elite tug of war athletes can produce force approximately 150% of the weight in a dynamic condition and approximately 200% of the weight in a static pulling and on the official lane. The order of lower limb movement during pulling backward exercise was rotating an ankle joint at toe off and places the toe out side. It helps sustaining the place of the leg land on against the load during swing phase of other leg. It can be considered that one of the skill during stance phase (Figure1). Generally, the order to use lower limbs in backward walking is taking off at a heel and dropping land at a toe. In current study, the order to use a lower limb during dynamic pulling exercise was taking off at a toe and dropping land at a heel. The kinematical differences were found between backward walking and pulling backward exercise, which was the order to use lower limb. Comparing Figure 1a and b, however the left greater trochanter moves back and forth, the right greater trochanter moves backward without returning. It may because, all subjects participated in this study hold a rope by right side of body during trials. Thus, the prevent study revealed one of the skills of dynamic pull against the tugging rope which was the well trained tug of war athletes had consciousness of the right side of a body, which was holding a rope, and possible to move backward without returning. The lower limbs angle displacements during TH were asymmetry (Figure 2). As the results showed in Figure 2, it was supposed that the left leg was used producing force and move slowly and right one was used for advance to the own territory and move quickly. The speed of center of mass was 0.21 ± 0.09 ms^{-1} in average during trials (Figure 3). The obvious fluctuation in center of mass speed was seen during the trial.

CONCLUSIONS: Our data revealed the biomechanical profiles in dynamic pulling exercises that the elite tug of war athletes can produce force approximately 150% of the weight in a dynamic pull on the official lane. Also, the order of lower leg movement was rotating an ankle joint at toe off and places the toe out side. It helps sustaining the place of the leg land on against the load during swing phase of the other leg. In addition, the order to use a lower limb during dynamic pulling exercise was taking off at a toe and dropping land at a heel. Moreover, however the left greater trochanter moved back and forth, the right greater trochanter moved backward without returning.

Photo 1 Dynamic pulling exercise.

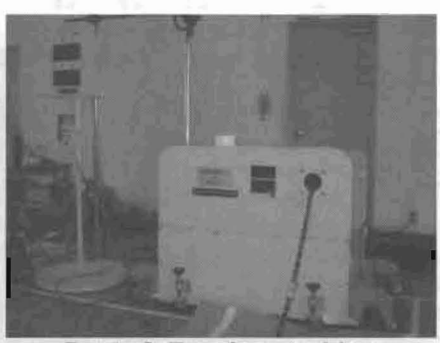

Photo 2 Tugging machine.

Table1 Physical characteristics of subjects (n=20).

	Age (yrs)	Height (m)	Weight (kg)	Experiences (yrs)
Mean	28.3	1.74	71.9	5.4
SD	3.3	0.04	6.0	1.7

Table 2 Static pulling forces of subjects (n=20).

	Maximal force (N)	70% maximal force (N)
Mean	1580.1	1106.1
SD	19.9	136.2

Table 3 The relationship between maximal pulling force and weight (n=20).

	Static Force (N)	SF/W (%)	Dynamic Force (N)	DPF/W (%)
Mean	1410.8	201.8	1041.6	149.0
SD	225.7	38.2	123.9	23.1

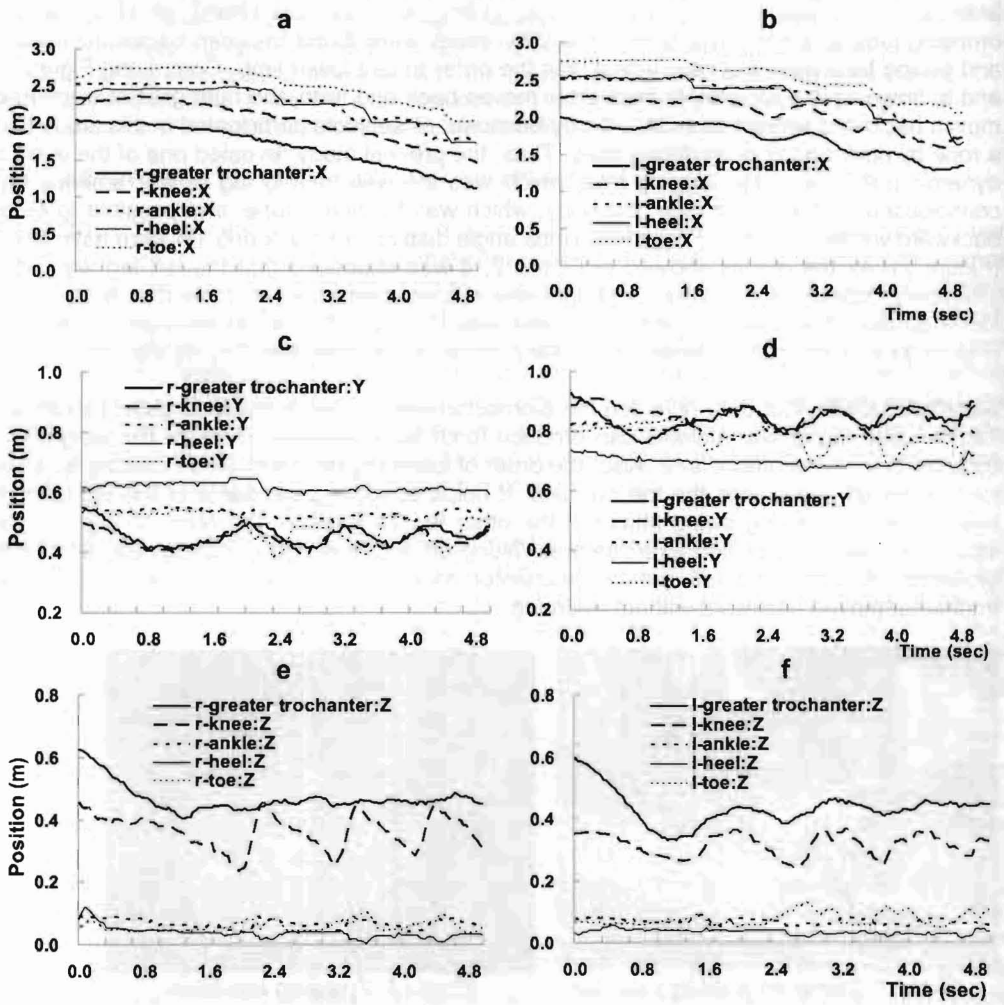

Figure 1 The displacement of right and left lower limb landmarks during trial of subject 1 in X,Y and Z axis.

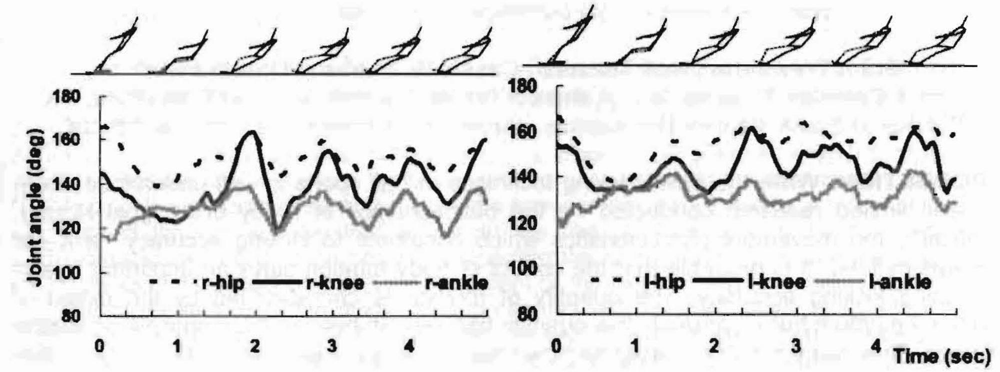

Figure 2 The displacement of right and left lower limb joint angle during trial.

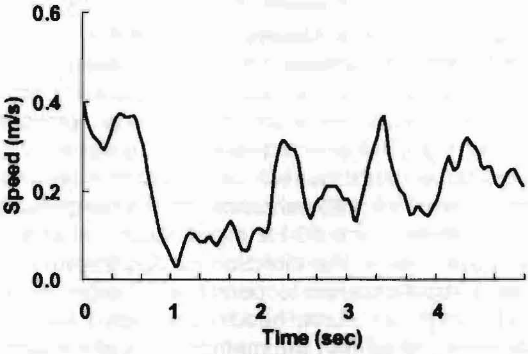

Figure 3 The displacement of COM speed during trial.

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