FAST FRONT KICK: GAINING INSIGHTS BEYOND THE DATA

Raul Landeo and Andrew S. McIntosh

The University of New South Wales, School of Safety Science. Sydney, Australia

The purpose of this study was to examine sets of kinematic variables obtained from Taekwondo fast front kick and to asses their potential use for movement analysis. Kinematic data were divided into three categories; i) Peak velocities (PV), ii) Normalised time to reach peak velocities (TPV) and iii) Intersegmental timing and calculated performance variables (TCV). Expert and novice participants (n=40) performed a set of three fast front kicks and squat and counter movement jumps. No correlation between TPV variables and skill (< 0.25) or execution speed (< 0.2) was found, while group mean differences are not significant (p > 0.52). Skill is better assessed from TCV (group mean differences p< 0.0001). A stronger correlation between peak velocities and jumping ability (0.84) than to skill (0.51) was found.

KEY WORDS: Taekwondo, skill, kinematics, strength

INTRODUCTION:

It has been stated (Andrews, 1982; Leonard, 1998) that a set of kinematic variables can portray the neurological behavior that gives rise to the execution of a movement pattern. Muscle activation timing and coordination can, for instance, modify the kinematics of a task execution and are therefore reflected in body segment kinematics. Kinematic variables are also determined by the effective force/s acting prior to and during task execution.

The human body is conceived as a system that behaves in a minimalist approach ie. it tries to reduce the metabolic cost of performing a motion pattern (Åstrand and Rodahl, 1986). To this end information pertaining to segment anthropometry, eg. mass and inertia, and segment dynamics, concurrent to some physical, biological and topological constraints imposed by the intended task are accounted for by the Central Nervous System (CNS) to generate appropriate signal commands for task execution. Some of these constraints are inherent to the task, i.e. a given motor action has to be performed in a specific way (technique) to achieve the desired outcome. CNS responses to task constraints are reflected in the kinematics of a task.

Thus, a set of kinematic data contains information on timing, coordination, the underlying strength and power abilities of the person executing the task, and the various constraints under which the task is executed.

Taekwondo's front kick (FK) was the subject task for this study. It consists of a sequential hip flexion followed by a rapid knee extension aiming at a target in front of the performer. It is a fast action that takes between 0.24 to 0.30 seconds (Joon, 1987), to be completed. Fast kicking actions are typically described based on kinematic markers such as peak velocities (Joon 1987), derived variables such as power (Robertson, 1985) and a set of segmental interactive moments (Putnam, 1991; Sorensen et. al. 1996). Skill level has also been assessed from achieved peak velocities (Opavsky, 1988). Kinematic outcome based movement analysis, however, may be limited in its capacity to fully describe the execution of a given task, especially if a particular feature of task execution, such as skill or conditioning, is under inspection.

It was thought that grouping variables according to the information contained on each of them; peak velocities, coordination and timing etc. may be an alternative method to evaluate kinematic data. Grouped variables have the potential to give detailed insights into the biomechanics of the execution of a FK by participants with varied kicking abilities and levels of physical conditioning. It was also thought that some variable groups may reflect more than others, specific kicking features that are intrinsic to the task, while other variables may be more representative of a particular participant's technical or physical ability. Thus, some of these variables may be used to characterize the kicking task and to distinguish it from other forms of kicking while other variables may be used to assess skill level, training effects and physical conditioning status of the performer. The aim of this study was to describe group kinematic variables and to determine their potential applications to movement analysis.

METHODS:

Following approval from the Human Research Ethics Committee (University of New South Wales) a sample of convenience of 40 male and female participants (20 expert and 20 novices), aged 22 ± 3.2 years was recruited to the study. Each participant executed *i*) a set of three fast front kicks to a screen target placed at an individually chosen distance in front of each participant, and, *ii*) squat (SJ) and counter movement jumps (CMJ). Two dimensional saggital views of kicks and jumps executions were recorded by a high speed camera (Phantom ®) with a 500Hz sampling frequency and digitized using WinAnalyse ® software. A standard marker set; shoulder, hip, knee, ankle and fifth metatarsal, was used for this study. Data were processed using user derived codes written in Matlab ®.
To investigate the kinematics of a FK execution three variable groups were defined; peak linear and angular velocities (PV), normalised time to reach peak velocities (TPV) and intersegmental timing and calculated performance indicators (TCV). PV consisted of peak thigh and leg segment angular velocities (ωThi, ωLeg) and peak hip (*v*H), knee (*v*K) and ankle (*v*A) linear velocities. TPV included normalised time to reach peak angular velocity for the thigh (*t*ωThi) and for the leg (*t*ωLeg) as well as time to reach peak linear velocities at the hip (*tv*H), knee (*tv*K) and ankle (*tv*A) joints. TCV consisted of variables calculated from PV and/or TPV. The defined TCV variables are the angular velocity ratio between segments (ω_{ratio}), intra-segment timing ratio (r_T), for each segment, normalised inter-segment timing index (t_i) and a performance index (*PI*).
The criteria used to determine the TCV are shown below:

$$\omega_{ratio} = \frac{\omega Leg - \omega Thi}{\omega Leg}$$

t_i→ Normalised time between ωThi and Leg maximum angular acceleration

$$r_T = \omega_{\max} \exp\left(- \frac{1 - t\omega_{\max}}{t\omega_{\max}} \right) - t_i \omega_{\max}$$

$$PI = (1 - t_i)\sqrt{(vA * \omega_{Leg} * \omega_{ratio})}$$

The rationale for variable group allocation is as follows: PV group variable aims at reporting on the peak velocities reached during the execution of a FK by the expert and novice groups. Skill level is confounded with the level of physical conditioning and task execution constrains in achieving peak velocities. That is, a high end peak velocity may be achieved, in spite of a poor technique, by physical conditioning alone; or, in spite of a good technique, and in the absence of a good physical conditioning, kicking end velocities may not be high. PV variable group is consequently insufficient to fully describe a FK execution.
A second variable group was therefore defined; TPV. It was thought that by enquiring into the timing profiles of the kicking action more technical, skill or some of the intrinsic features of the task execution could be revealed. That is, by looking into how a particular kick execution is timed the skill level or the intrinsic nature of the task could be better assessed. A third variable group, CTP is defined when theoretical forms of open link systems (summation of speed principle) are used as reference. PV and TPV variables are used as inputs to estimate performance indexes. FK execution displaying high end velocities while approaching to the theoretical forms of open link system are considered to have a better performance index, and as such display more appropriately the skill level of the performer.

RESULTS AND DISCUSSION:

Based on criteria by (S∅rensen, 1996) the fastest kick from each participant was analysed. PV, TPV and TCV variables group means for experts and novices are shown in tables 1, 2 and 3. Table 4 shows the group means for SJ and CMJ data, as well as the height difference in between jumps. Group mean differences were assessed by a T-test (p<0.05). Since FK aims to achieve a high end velocity of the distal end of the distal segment a correlations between PV, TPV, TCV and control variables to vA_{max} and skill level were also conducted.

Table 1 PV variables mean group differences, expert vs. novices. PV variables correlation (r) to peak ankle velocity and to skill is also shown. P-value for T-test between expert and novice groups.

Variable	Expert n (20) Mean (STD)	Novice n (20) Mean (STD)	P value	*v*A Correl	Skill Correl.
ωThi(rad/s)	9.92 (2.64)	8.70 (1.74)	0.05	0.75	0.26
ωLeg (rad/s)	18.65 (3.34)	14.45 (2.78)	0.00	0.85	0.57
*v*H (m/s)	0.97 (0.51)	0.82 (0.41)	0.23	0.31	0.16
*v*K (m/s)	4.29 (1.06)	3.58 (0.86)	0.01	0.91	0.35
*v*A (m/s)	10.39 (1.95)	8.18 (1.76)	0.00	1.00	0.51

All but the vH of this variable group show significant differences between groups. The correlation between vH and peak end velocity (0.31) and skill (0.16) are weak. This suggests that peak vH is not as important for the execution of a FK as may have been thought, given the fact that a FK is a proximal to distal motion pattern. It can also be inferred that reporting on vH during the execution of a FK holds little relevance for describing the execution of a FK. In light of significant group mean differences for PV variables it may also be inferred that these variables, with the exception of vH, can be used to assess training gains in Taekwondo athletes.

Table 2 TPV variables mean group differences, expert vs. novices.

Variable	Expert n (20) Mean (STD)	Novice n (20) Mean (STD)	P value	*v*A Correl	Skill Correl.
*t*ωThi	0.43 (0.06)	0.44 (0.04)	0.62	0.17	0.02
*t*ωLeg	0.72 (0.07)	0.70 (0.05)	0.52	0.01	0.09
*tv*H	0.27 (0.18)	0.26 (0.19)	0.82	-0.07	0.03
*tv*K	0.34 (0.13)	0.42 (0.12)	0.06	0.19	0.25
*tv*A	0.66 (0.07)	0.71 (0.07)	0.70	-0.04	-0.05

There is no correlation between TPV variables and *v*A (< 0.19) and skill level (<0.25). Since the sensitivity of these variables to skill and/or speed is low it can be suggested that their magnitudes are inherent to the task and not the participant. It then follows that that these intra-segment timing variables reflect the nature of the task and, to an extent, the constraints imposed on the performer. It may then be appropriate to suggest that these timing variables are governed and controlled at higher levels of CNS, perhaps by muscle mechanics (muscle length) driven mechanisms.

The practical potential use of TPV variables is that they can be used to distinguish FK from other forms of fast kicking actions such as soccer kicking, and to prescribe more specific conditioning programs targeting the uniqueness of the FK execution.

Table 3 TCV variables mean group differences, expert vs. novices.

Variable	Expert n (20) Mean (STD)	Novice n (20) Mean (STD)	P value	*v*A Correl	Skill Correl.
ω_{ratio}	0.43 (0.08)	0.47 (0.07)	0.00	0.30	0.62
T*i*	4.61 (3.33)	3.78 (2.22)	0.00	-0.28	-0.54
r_TThi	-0.72 (0.42)	-0.93 (0.65)	0.13	0.14	0.20
r_TLeg	5.41 (1.97)	4.71 (1.72)	0.16	0.36	0.19
PI	0.47 (0.23)	0.58 (0.18)	0.00	0.89	0.70

TCV r_T variables also show a weak correlation to *v*A (<0.36) and to skill (<0.20). Although these were classified as derived variables, they largely depend on *t*ωThi and *t*ωLeg which are

TPV variables. The remaining TCV variables as well as the control tasks (SJ and CMJ), reflect well on both skill level and physical conditioning. With the available data it is difficult to separate the impact of skill or conditioning level on kicking speed, as skill gains by way of training may also induce increases in jumping ability. The correlation between skill and jumps is strong (>0.56). The correlation between control tasks and skill to *v*A is however stronger for the jumps tasks (>0.83) than skill (0.51).

Table 4 Control tasks mean group differences, expert vs. novices.

Variable	Expert n (20) Mean (STD)	Novice n (20) Mean (STD)	P value	*v*A Correl	Skill Correl.
Skill				0.51	1
SJ	0.44 (0.07)	0.35 (0.07)	0.00	0.84	0.58
CMJ	0.47 (0.05)	0.40 (0.06)	0.00	0.83	0.57
∆Jumps	0.03 (0.02)	0.06 (0.02)	0.00	-0.77	-0.56

In light of these results it may be appropriate to use 'raw' PV variables to monitor physical conditioning progress, along with other assessment tools and to favor the use of TCV variables to assess skill development. It is proposed that adaptation of some of these variables to other specific tasks, such as throwing or other forms of kicking, will allow better monitoring of the various requirements to execute a given task, to either enhance performance or assess skill acquisition.

REFERENCES:

Andrews, J.G. (1982). On the relationships between resultant joint torques and muscular activity. *Medicine and Science in Sports and Exercise,* 14(5), 361-367.

Åstrand, P.O. and Rodahl, K. (1986). Physiological Bases of Exercise. McGraw-Hill International Editions. pp.1-10.

Joon, S.N. (1987). An analysis of the dynamics of the basic Taekwondo kicks. *U.S. Taekwondo Journal*, IV(2): 10-15.

Leonard, C. T. (1998). Neural Control of Human Locomotion. In Leonard, C. T. (Ed.) The Neuroscience of Human Movement. Mosby -Year Book Inc. pp. 146- 175.

Opavsky, P. (1988). An investigation of linear and angular kinematics of the leg during two types of soccer kick. In: Science and football, T. Reilly, A. Lees, K. Davids, & W.J. Murphy, eds., pp. 456-459. E. & F. N. Spon, London.

Putnam, C. A. (1991). A segment interaction analysis of proximal-to-distal sequential motion patterns. *Medicine and Science in Sports and Exercise*, 23, 130 -144

Robertson, D. G. E. and Mosher, R.E. (1985). Work and power of the leg muscles in soccer kicking. In *Biomechanics IX-B.* 533- 538

S∅rensen H., Zachoi, M. Simonsen, E.B. Dyhre-Poulsen, P. and Klausen, K. (1996). Dynamics of the martial arts high front kick. *Journal of Sports Sciences*, 14, 483-495.