A CONSIDERATION OF QUANTITATIVE EVALUATION OF DEXTERITY IN SPORTS EXERCISE

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The aim of this study was to quantitatively evaluate dexterity on athletic motions. Subjects were three skilled and three non-skilled weight lifters. They performed power clean that is a strength-training motion. We measured trajectories of joints by using motion capture system, and calculated joint torque according to dynamical equations using only kinematic data. In order to evaluate the strength of stretch reflex and that of proprioceptive feedbacks, we employed curve fitting with the recursive least squares method in our proposed torque model that includes a term caused by stretch reflex and feedback terms with respect to the COP and COM position. The results show that the calculated coefficients reflect some dexterous behavior of skilled motions.

KEY WORDS: stretch reflex, torque model, recursive least squares method.

INTRODUCTION: In some sports actions highly skilled athletes maintain their articulations at respectively low stiffness state, the purpose of which will be two folds. One is to comply and absorb contingent external disturbances, and the other one is that the low-stiffness allows them to effectively utilize reactions stemming from stretch reflex against applied external force or torque. It sometimes requires them a long and hard training to acquire the capability to dynamically adjust the stiffness according to the change of external interferences. It is obvious that disciplined actions such that do not rely on any neurological feedback passing through cerebral cortex or cerebellum because of requiring prompt responce. Bernstein (1996) duly defines the *dexterity* as an ability in the above mentioned context, "*Dexterity is the ability to find a motor solution for any external situation, that is, to adequately solve emerging motor problem.*" Let us come back to our problem from the point of Bernstein's view. Making articulations relax, which rephrases to gain the low-stiffness state, allows athretes not only to passibly adapt abrupt change of external force or torque, but also to react or regulate it by the response due to the stretch reflex after short latency time that is necessary for proprioceptive feedbacks on the spinal code level (Akazawa et al. 1983).
We took a power clean (PC) motion known as a weight-lifting training(Nagao, et al. 2012) as a typical athletic motion to evaluate dexterous behaviours mentioned above. Because it is a sufficiently fast motion to achieve a required task (=lifting barbel) while sustaining a posture stability. We proposed a "torque model" that includes a feedback term with respect to the vertical positin of the center of mass (COM), a feedback term with respect to the center of pressure (COP) and a term with respect to stretch reftex. To quantitatively evaluate them, we employ the recursive least-square method (RLSM) to calculate the time courses of the coefficients multiplied in each terms in the torque model. The methodology of this paper is identical to the previous paper (Nagao, et al. 2013) but this paper summarizes the results of 6 subjects (3 skilled, 3 non-skilled) to assure reproducibility and generarity of the proposed torque model and the proposed analytic method.

METHODS: The subjects were six male college students. They were classified into two categories, the skilled and the non-skilled, based on a typical criteria as "PC 100% one repetition maximum/body weight" exceeding 1.0 or not. Table 1 shows the subjects' demographic data.
They performed PC of which intensity was set at 70% of 1 RM. The position trajectories of markers attached on the subjects' bodies during PC were recorded by motion capture system (Cortex3, Motion Analysis). Analytic period of PC motion was from onset of barbell lifting to the standstill.

Table 1: Subjects' physical characteristics

	Group					
	Skilled (n = 3)			Unskilled (n = 3)		
Variable \ Subj.	A	B	C	a	b	c
Age [yr]	25	21	22	21	19	22
Height [m]	1.70	1.72	1.72	1.75	1.78	1.77
Weigth [kg]	63.6	68.3	70.2	71.0	72.5	66.5
PCmax [kg]	90.0	75.0	80.0	50.0	65.0	55.0
%PCmax [−]	1.42	1.10	1.14	0.70	0.89	0.83

%PCmax : 100% one repetition maximum/body weight

A 9-body segment rigid-body model in sagittal plane was composed. The angle, angular velocity and angular acceleration of each joint were calculated. Mass and moment of inertia of the segments were derived from the body segment parameters (Ae et al. 1992). The joint torque τ_i of hip, knee and ankle were calculated according to the dynamic equations given by the Lagrange's formulation (Robertson et al. 2004). Center of pressure (COP) was also calculated from the obtained kinematics data (Takanishi et al. 1985). We employed the torque model that includes three term mentioned above (Nagao et al. 2013). The schematic diagram of analysis with torque model and RLSM were summarized in Figure 1.

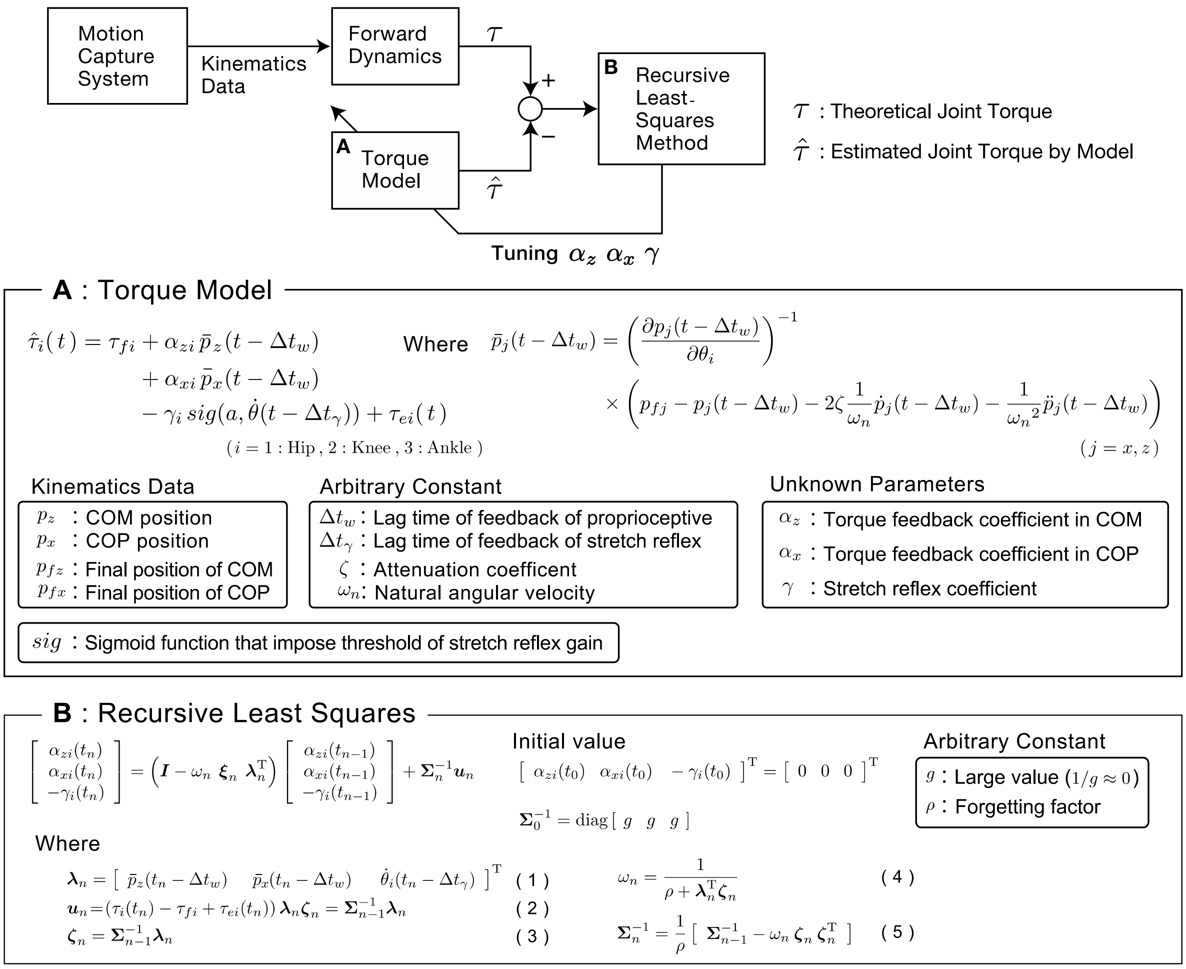

Figure 1: Flow of the numerical analysis

The outstanding characteristics of this method are as follows; (1) The torque model include a term of stretch reflex that obeys a sigmoid function in terms of angular velocity to express actual phenomenon of the stretch reflex, (2) The RLSM allows to calculate dynamic change of coefficients as time variables. Athletic motions and their nerve control on the spinal cord level were varied in short time. So we consider the RLSM being superior to the normal Least square method to be used for analysing such a dynamic motion. (3) There is no need to calculate inverse matrix that is necessary for a normal LSM, which allows us large-scale computations.

RESULTS & DISCUSSION: Figure 2 shows hip, knee and ankle angle during PC motion of two groups: three skilled and three non-skilled, It is observed that three subjects in each groups had joint angle displacements in almost the same pattern, and that knee flexion-extension occurs in the skilled group, which suggests that the skilled has acquired “double knee bent (DKB)” that is an unique technique in skilled weight lifters (Chiu et al., 2005). This fact clearly suggests the selection of each group’s subjects in our study was reasonable.

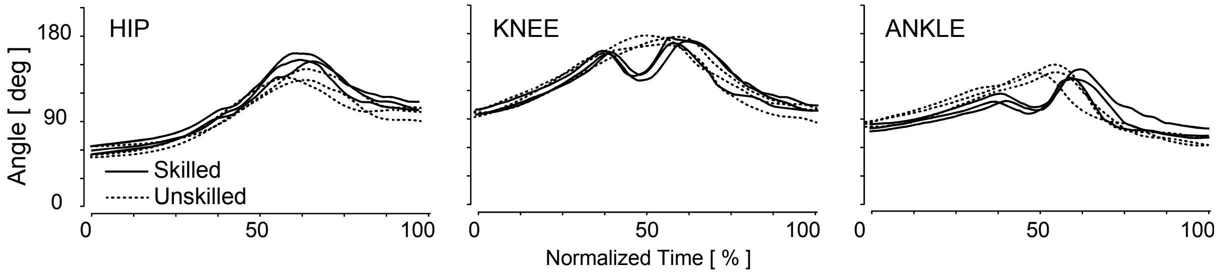

Figure 2: All subjects’ hip, knee and ankle joint angle data

Figure 3 and 4 shows results of α_{zi}, α_{xi} and γ_i during PC motion. Constants used in the torque model and RLSM computation are selected in the range of; Δt_γ = 20~50 ms, Δt_w = 10~30 ms, ω_n = π/4~2π rad/s, ζ = 0.1~1.0, ρ = 0.95~0.99, g = 1000, to minimize the torque error ($|\tau - \hat{\tau}|$ in Fig.1). As shown, the time-course of three coefficients shows some apparent consistency among the members in each group but shows apparent difference between two groups.

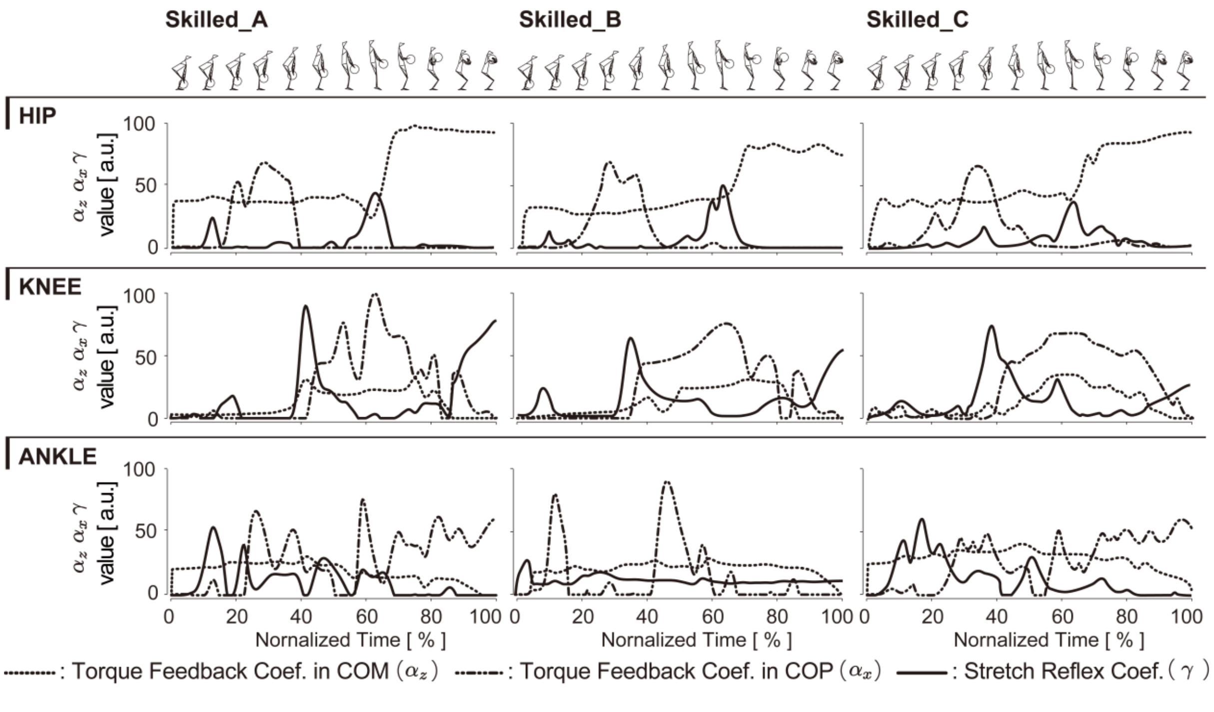

Figure 3: Skilled parameters value of hip, knee and ankle calculated from torque model

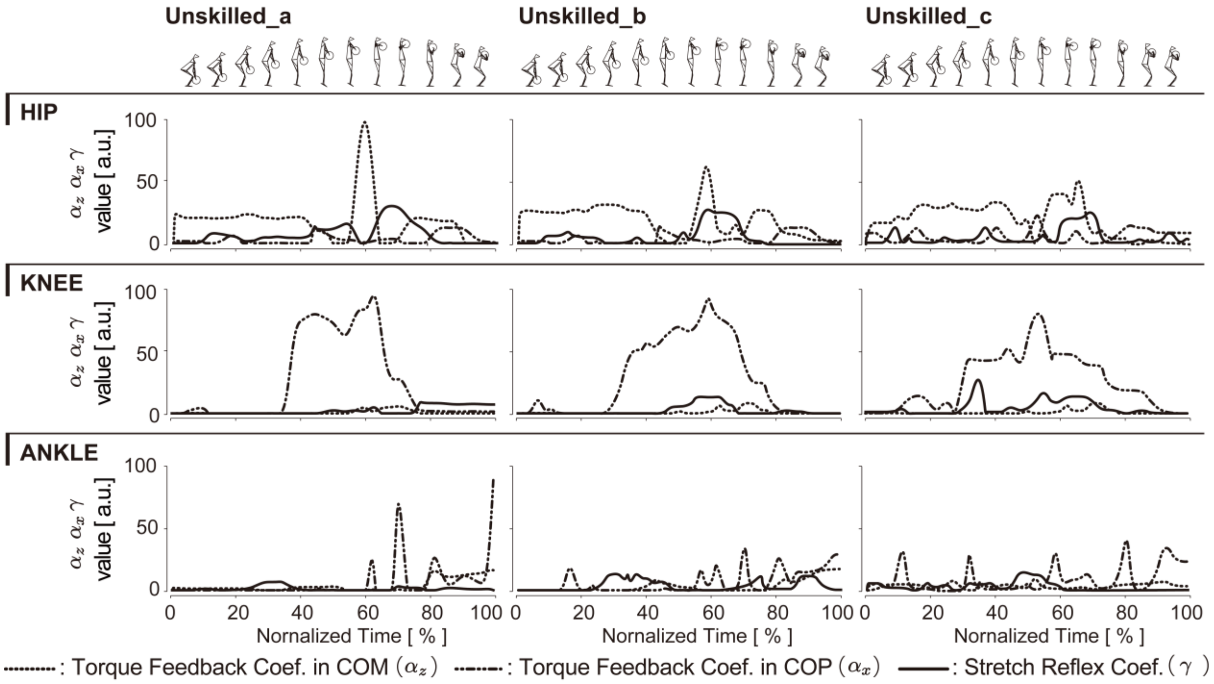

Figure 4: Unskilled parameters value of hip, knee and ankle calculated from torque model

This fact suggests the high reproducibility and generality of the torque model. There are some noteworthy points. (1) At the moment of almost 40% in normalized time, γ of the knee is increased rapidly in all skilled performers. It is possibly to say that it represents the Stretch-shortening cycle behavior of knee extensor muscles. Because the knee extensor muscles are stretched with knee flexion. (2) Coefficient α_z in all skilleds' hip shows larger value than any other joint's α_z. It suggests that skilled lifted the barbell mainly by controlling the hip joint torque as Enoka (1988) reported.

CONCLUSION: In this paper, we present an evaluation method of skilfulness in athletic motion. Our torque model includes a feedback term caused by stretch reftex and a proprioceptive feedback term caused by COP position. We employed the RLSM to calculate the time courses of their coefficients. A prominent advantage of the proposed method is that it provides time-variant coefficients continuously. We analysed 3 skilled and 3 non-skilled. Experimental results indicate that each coefficient shows some consistent tendencies in each group. This fact suggests high reproducibility and generality of the proposed torque model.

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