AN ARTIFICIAL NEURAL NETWORK METHOD FOR PREDICTING LOWER LIMB JOINT MOMENTS FROM KINEMATIC PARAMETERS DURING COUNTER-MOVEMENT JUMP

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The purpose of this study was to develop an artificial neural network (ANN) model for predicting the joint moments of lower limbs using solely the kinematic parameters during counter-movement jump (CMJ). Nine female volleyball players performed CMJ. The joint moments were calculated from experimental data by inverse dynamics (called "measured joint moments" in this study). A "303-3-303 ANN model" was developed with 303 neurons in input layer, three neurons in hidden layer and 303 neurons in output layers. The input variables were the left lower limb extension / flexion joint angles, and the output variables were left lower limb extension / flexion joint moments. The results revealed that the ANN model fitted the experimental data well indicating that the model developed in this study was feasible in the assessment of joint moments for CMJ.

KEY WORDS: artificial neural network, joint moment, CMJ.

INTRODUCTION: Vertical jump has been often used to assess an athlete's lower limb muscular strength and power (Bosco, 1999). However, the information of jumping height is not enough for athletes to promote the performance because it can only indicate the result of the action of muscles at the lower limbs to accelerate the body segments upward. Human limb motions are caused and controlled by joint moments (Zernicke, 1996). Therefore, joint moments can provide direct information on both the muscle strength and neuromuscular control.

Inverse dynamics analysis is needed to calculate joint moments, which requires not only kinematic data but also ground reaction forces (GRF) and anthropometric data (Robertson et al., 2004). Since the procedure of inverse dynamics analysis is relatively complicated, this is not a practical tool for on-field instructors and physical educators. It will be helpful to develop a quicker and simpler processing method in order to obtain the joint moments. Artificial neural network (ANN) is a computational technique that has the inclination for storing experimental knowledge and making it available for application (Schollhorn, 2004). The ANN modeling has been widely adopted in the area of clinical biomechanics. Liu et al. (2009) develop an ANN model for prediction joint moments at hip, knee and ankle joints using GRF during counter-movement jump (CMJ) and squat jump (SJ). The purpose of this study was to develop an ANN model for predicting lower limb joint moments at hip, knee and ankle using solely the relevant kinematic parameters during CMJ.

METHOD: Nine female students from a college volleyball team (age: 20±1.01 years, height: 165±6.24 cm, mass: 59±4.82 kg) performed CMJ three times (one random trial data of each subject was used). The kinematic and kinetic data were measured with a 7-camera motion analysis system (Vicon 512, Oxford Metrics, U.K.) and two force plates (AMTI, Advanced Mechanical Technology, U.S.A.). The joint moments at hip, knee and ankle were calculated by inverse dynamics (called "measured joint moments" in this study).

A feed-forward back propagation network comprised of one input, one hidden and one output layer was developed. The input variables of the ANN model were left limb extension / flexion joint angles, and the output variables were left limb extension / flexion joint moments during the support phase of CMJ. Since the movement times were different among subjects, all input and output variables were normalized to 100% of support phase. Moreover, the input variables were scaled and the output variables were rescaled before and after running the ANN model. The data of eight randomly chosen subjects were used for training of the ANN model. The other one subject's data were used to verify the performance of the ANN model between the ANN-predicted and inverse dynamics calculated values. The ANN model was implemented using Matlab 7.3.0 (R2006b).

RESULTS: After trial-and-error procedure, a “303-3-303 ANN model” with the minimal root mean square error (RMSE) was developed with 303 neurons in input layer, three neurons in hidden layer and 303 neurons in output layers. The figure 1-3 shows that the ANN-predicted curves of joint moments fit the measured curves well. The correlation coefficients between the measured and ANN-predicted joint moments during the support phase of CMJ (Table 1) were all more than 0.94. The results revealed a high level of agreement between the ANN-predicted joint moments and those experimentally measured.

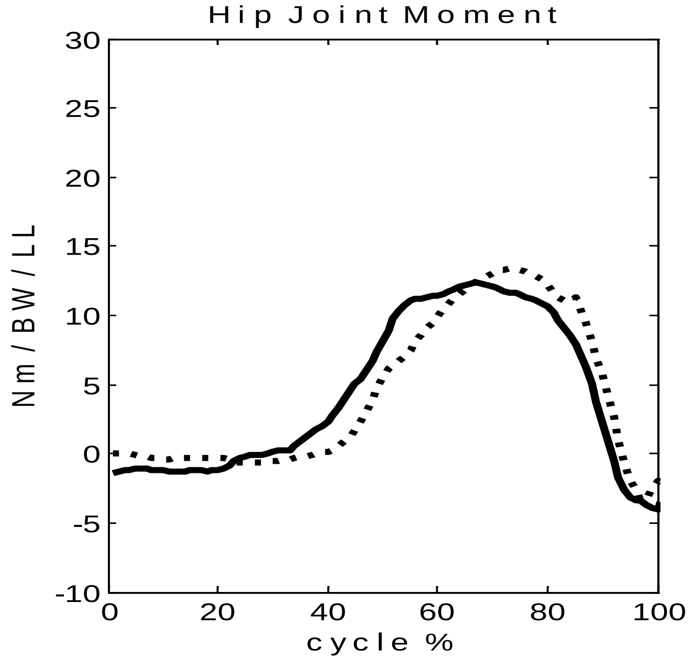

Figure 1. The measured (dotted line) and ANN-predicted (thick line) joint moments at hip during CMJ

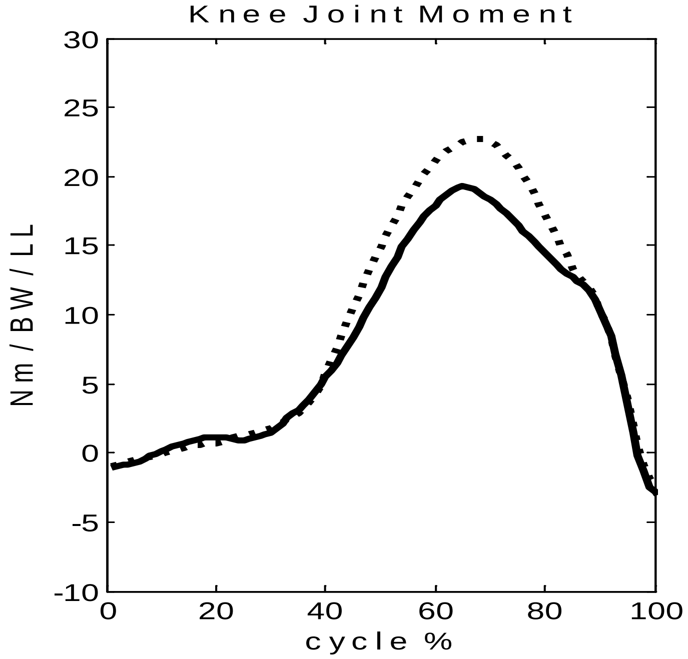

Figure 2. The measured (dotted line) and ANN-predicted (thick line) joint moments at knee during CMJ

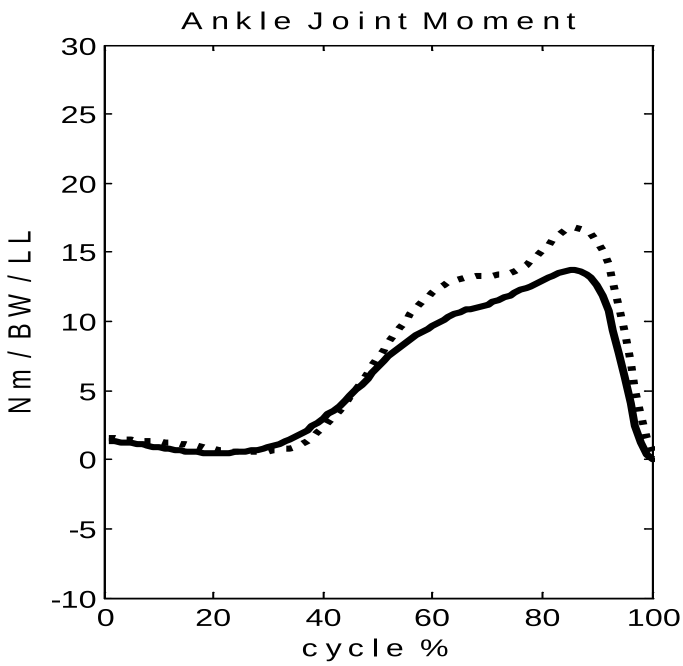

Figure 3. The measured (dotted line) and ANN-predicted (thick line) joint moments at ankle during CMJ

Table 1. The correlation coefficients (r) between the measured and ANN-predicted joint moments

Joint moments	r
Hip (extension / flexion)	0.9418
Knee (extension / flexion)	0.9958
Ankle (extension / flexion)	0.9920

DISCUSSION: The correlation coefficients between the measured and ANN-predicted joint moments during the support phase of CMJ were all more than 0.94, indicating a high level of agreement between the measured and ANN-predicted joint moments. The ANN-predicted and measured joint moments agreed very well both in trend and magnitude, suggested the ANN method with solely kinematics parameters is capable of producing very approximate measured joint moments of lower limbs during CMJ. In addition, through the fitting quality of the curves, it was confirmed that the ANN possesses the abilities of filtering and admitting noise (Schalkaff, 1997).

However, the results were from only one sport item, and there was only one subject's data used to verify the performance of network, so our ANN model must be used carefully for other kinds of population. In the future, training of the ANN-model with greater sample size of training data will increase its accuracy and will be helpful for its application in the evaluation of athletes' muscular strength and neuromuscular control of the lower limbs.

CONCLUSION: A feed-forward back propagation ANN model comprised of one input, one hidden and one output layers was developed by trial-and-error procedure to predict the lower limb joint moments using solely the relevant kinematic parameters during CMJ. The results indicate that the ANN model developed in this study is feasible in the assessment of lower limb joint moments without inverse dynamics calculation for CMJ. After improvement of the ANN model with large number of subjects, it is believed that this kind of ANN model might be used to evaluate in depth the athletes' joint moments in lower limbs.

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