CONSTRUCTION OF AIRBORNE MOVEMENTS AND MODEL APPROACH FOR LEARNING

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The purposes of this research were a) to identify differences in the biomechanical description of movements between the biomechanist (external view), the athlete (internal sight) and the coach system (internal sight from external view; Lippens, 1997) and b) to supply applicable and relevant information for learning sport skills. The research consists of biomechanical modelling, collection of anthropometric and kinematic data, analysis, construction of a learning model and its application to practice. Results of the research are: (a) The inertial and the non-inertial system as well as coupling of body segments establish the differences between the views 1 to 3. (b) Joint rotations are not identical with the muscular moments, passive rotations (McGeer, 1990) can occur. (c) Knowledge of muscular moments, "critical phases" and passive phases simplify learning of motor skills.

KEY WORDS: motor learning, internal / external view, passive phases, critical phases, muscular moments, anthropometry

INTRODUCTION: Three different systems, are involved in motor learning. These are the biomechanic system, the athlete system and the coach system. Biomechanists describe the movement in a system which is fixed to the environment (External View). The athlete controls his muscles in a system fixed to the body (Internal Sight). The coach translates a visible movement from the environment system into muscle control information in the body system (Internal Sight of External View). The aims of this study are to identify differences between these systems, to study interactions of body segments and their influence on motor learning and to find relevant and easily applicable information for learning. This leads to the development of a biomechanical model that needs anthropometric data for input, collected by a new method.

METHOD: For the study, a trampolining skill was chosen, the vertical takeoff without angular momentum and landing on the back (Figure 1). The skill is characterised by the fact that the change of the trunk angle during the airborne phase is not caused by an angular momentum.

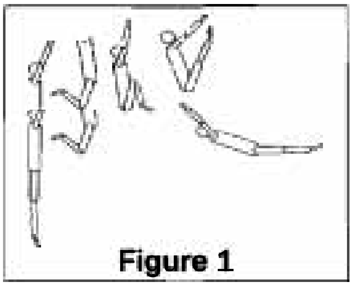
Figure 1

Model Construction: A 2-dimensional 5-segment rigid body model was constructed, consisting of arms, head and trunk, thighs, shanks and feet. The model works on the basis of Lagrange's dynamics. The software package DADS (Dynamic Analysis and Design System, Haug 1989) was used for modelling. The program allows carries out dynamic and inverse dynamic analysis, so that the net joint moments and net joint muscle moments can be calculated. The input data of the model are anthropometric and kinematic data.

Data Collection (1) - Anthropometical Data: A method developed by Shan (1995) was utilised in this study. The process of the method is as follows: I) Measure 15 characteristic profiles of a human body; 2) Reconstruct the body surface from the profiles utilising AutoCad software which leads to 10,000 3-D body surface points; 3) subdivide the body into thousands of tiny columns using these points and calculate anthropometric data such as segmental masses, centres of mass, radii of gyration and moments of inertia. Sixty subjects with a mean age of 28.1 years took part in this study. The subjects were 15 female Germans, 15 female Chinese, 15 male Germans and 15 male Chinese. The average body weight and height of the subjects are 56.9 kg and 1.66 m for the Chinese, 71.1 kg and 1.75 m for the Germans. Segmental mass and segmental lengths were related to these data.

Furthermore 792 correlation and regression analyses of body weight and/or height as independent variables were made.
Data Collection (2) - Kinematic Data: A well trained sport student performed the airborne movement. The measurement of shoulder joint, hip joint, knee joint and ankle joint as well as three initial conditions (vertical velocity of CG, absolute trunk angle and trunk angle velocity) was done using a Video Movement Analysis System (OrthoData Ltd.)
Analysis and Identification: 1) Joint angle and joint angle velocity are usually used to describe the skill in the external view, whereas net joint muscular moment supplies the joint rotation control signal in the internal sight. Therefore, the difference between external view and internal sight can be identified by comparing the angular velocities and moments. 2) The influence of anthropometric data on the change of the trunk angle was studied by simulation. The aim was to see to which extent the anthropometry affects the movement (internal sight from external view). 3) Alternative joint rotations were simulated to determine critical phases or to develop new skills. Critical phase means phases in which small changes in the movement lead to totally different results. 4) Joint moments, physical moments (gravity etc.), and muscular moments during the movement and the landing position were also analysed by using individual anthropometric data and inverse dynamic analysis in order to supply information for preventing injuries and for simplifying learning.

RESULTS AND DISCUSSION: For examining accuracy of the model, the measured and calculated trunk angle vs. time were compared (Figure 2). The error rate of 6 % is small enough for analysis and simulation.

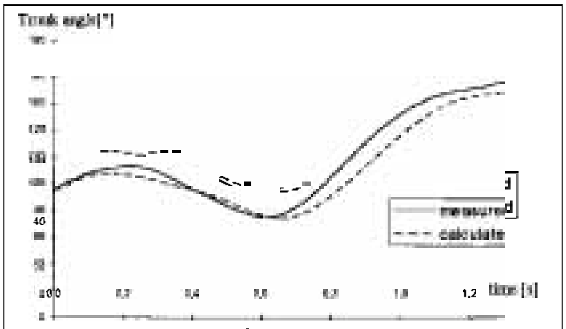

Figure 2

External vs. internal view: The results of dynamic and inverse dynamic analysis show that the correlations of joint angular velocity, joint moments and joint muscle moments are only small. Figure 3 shows e.g. that from 0.16 - 0.42 s the muscle moment in the knee joint can be neglected, while the angular velocity changes significantly. That means that joint rotation happened with hardly any muscle control. This is called 'passive rotation'. The contrary situation can be seen be seen from 0.9 - 1.2 s. In this phase a big muscle moment is needed just for fixing the joint. The reason for this deviation between movement and muscle action are two fold: (a) influence of structures in the neighbourhood and (b) non-muscular forces such as gravity and inertial forces (centrifugal force, Coriolis force,...,) as shown in Figure 4. In Figure 4a a skeleton arm with extensor and flexor in the elbow joint is shown. It is assumed, that the system has the conditions that extensor force = flexor force, the shoulder rotation axis is fixed in space and no arm movement happens. If the extensor is cut off, a rotation in the shoulder joint will occur without an applied moment. It is obvious that the passive rotation of the shoulder joint is caused by the rotation of the elbow joint. This means that a non-proper movement of a segment may be caused by the movement of neighbouring segments. Figure 4 b shows an example of the influences of the non-muscular force gravity and segment position on the moment. For the same extension of elbow joint (e.g. from 90" to 180°), very different muscle moments are needed according to different shoulder joint angles β (e.g. $\beta=0°$ or 90" or 180"). Generally speaking, the influence of non-muscular forces (gravity and inertial forces) is dependent on the movement conditions of a system. The difference between movement and muscular momentum and such the difference between external view and internal sight is caused by the difference between inertial and non-inertial systems plus the interaction between neighbouring segments. In other words, the description in the inertial system, which is the system of the spectator and coach (for example: impulse = A momentum) is no more suitable for the non-inertial system in which the athlete controls his movement.

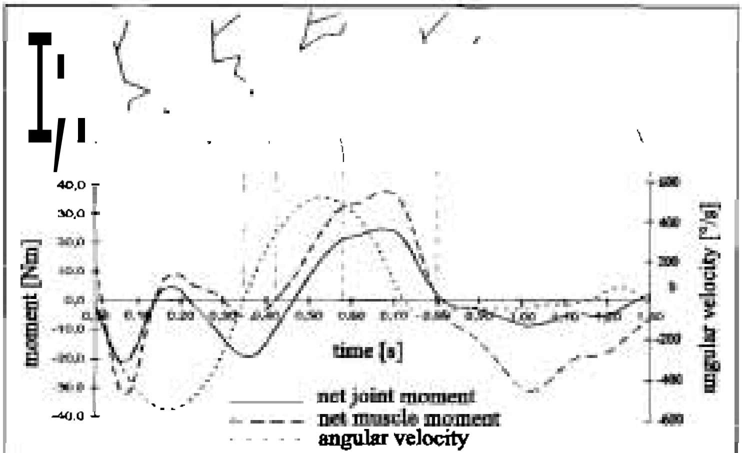

Figure 3

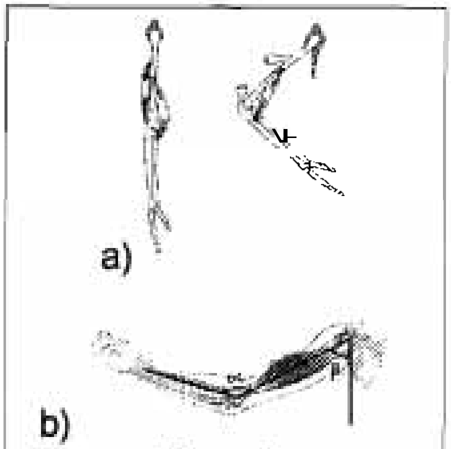

Figure 4

Chinese vs. Germans: The statistical analysis of the anthropometric data shows significant differences between Chinese and Germans both in absolute values and values related to body height and body weight. For the same body weight and height: (a) The head of a Chinese is 2.6% (male 3.0%, female 2.3%) heavier than that of a German. (b) The leg of a German is 1.7% (male 1.6%, female 1.8%) heavier than that of a Chinese. (c) The trunk of a Chinese is 1.8% (male 1.9%, female 1.7%) longer than that of a German (d) The leg and arm of a German are 1.8% and 1.6% longer than those of a Chinese respectively. According to these significant results, Chinese in general have bigger heads, longer trunks as well as shorter legs and arm in comparison with Germans. The following result was highly surprising: In contrast to Germans for the average Chinese the head is heavier than the arms, this applies especially for Chinese women. In order to determine the influence of the anthropometry on airborne movement, both absolute and relative differences were utilised in the simulation. For the absolute case, anthropometric data of two women (a Chinese woman, 1.55 m, 46 kg and a German woman, 1.70 m, 65 kg) and the same joint rotations were used. The results show that the change of the trunk angle of the small Chinese is greater than that of the German woman. In the landing phase, the trunk angle of the Chinese woman is greater than 180". This means landing on the head. So for the prevention of injury, rotations must be reduced. This might have the consequences that coaching literature should not be simply translated into foreign languages but it should also be adapted to significant differences in the anthropometric data of the average athlete in different countries. For studying the influence of relative differences in the anthropometric data, four groups (a Chinese man a Chinese woman, a German man, a German woman) were chosen. The anthropometric data were calculated using body weight (65 kg) and body height (170 cm) with the help of regression equations established in this study. The simulation shows that the relative difference has little influence on airborne movement. According to these results, the difference between internal sight and external view is mainly affected by body height.

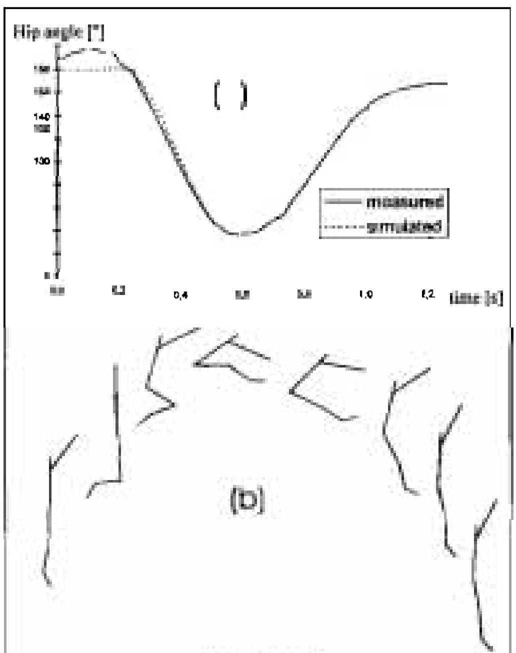

Figure 5

Critical phases and new skills: In the next step we looked for critical phases and new skills by varying one joint rotation while keeping the others unchanged. A very critical phase was found in the hip movement, namely the extension of the hip joint at the beginning. A straight, not over-extended hip at the beginning (Figure 5 (a)), leads to landing on the feet (Figure 5 (b)) instead on the back, which is often to be seen in the learning practice. When searching for new skills we studied variations of the arm movement. The simulation shows that rotating the arm clockwise or counter clockwise makes landing on the back possible. Only a few people can do such a skill because of anatomic conditions in the shoulder joint. Finally, the simulation of internal load to joint and to muscles showed that the airborne movement is safer than take off and landing.

A LEARNING MODEL AND ITS' EXPERIMENT INVESTIGATION: Based on the results, a flight phase learning model was constructed which consists of: 1) A study of the skill. 2) A search for critical phases which should be emphasised when learning. 3) Looking for passive phases in order to simplify the motor control for learners. 4) Measuring the individual data of the learner for adapting the model in terms of movement and load. The core of the model is to utilise the muscle moment as a movement control signal instead of the visible movement. The advantage of this approach is the simplification of the motor control because passive phases can be identified and neglected in the learning phase. The steps of the model are shown in Figure 6. 1) The skill is studied and the model is constructed by inputting kinetic and anthropometric data of a master. 2) Anthropometric data of a learner are input and it is checked if the skill can be transferred to him without overload. 3) Critical phases (for emphasising) and passive phases (for neglecting) are identified. 4a) Muscle moments, critical and passive phases are displayed to the learner. 4b) Alternatively, new or modified skills are constructed and the circuit is started at '1' again. The model was validated in learning the studied skill in a trampoline course at the University of Muenster. Twenty sport students (divided into two groups) took part in the experiment. The experiment examined two aspects of learning, namely, knowledge and performance. The first group learned the skill in a conventional method with visible information only. The second group added muscle control information. The experiment showed that, in the students' opinion, the second method is superior and leads to better understanding of the skill (knowledge). Moreover, the video analysis shows that the second method results in better performance of the skill. Experts rated the performance of the muscle control group better than the conventional method group (p=0.26).

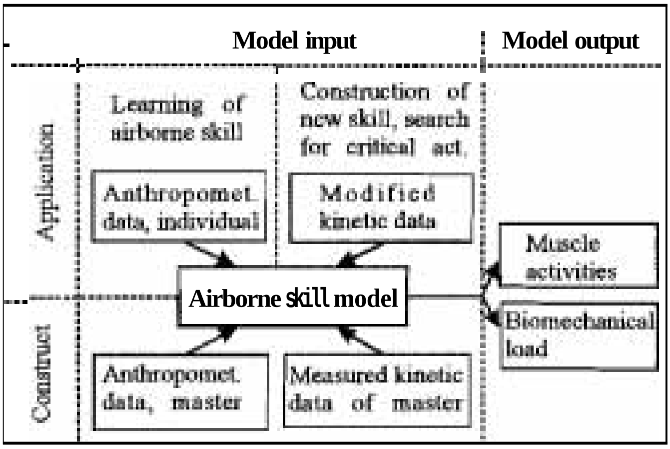

Figure 6

CONCLUSION: A biomechanical analysis of joint muscle moments in an airborne movement is well suited for improving communication with athletes and coaches as well as for improving efficiency of learning by simplifying the motor control using passive phases.

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