CAN BIOMECHANICAL DIAGNOSTIC PROFILING IDENTIFY THE EFFECTIVENESS OF SPECIFIC TRAINING EXERCISES?

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This study investigated the use of a diagnostic and prescriptive pathway that aims to determine the effectiveness of specific training exercises. The model was tested by examining if the effects of drop jump (DJ) training on countermovement jump (CMJ) performance could be explained by the degree to which performance determining factors (PDFs) for the CMJ were overloaded. Participants trained with DJ for 8 weeks yet no change in CMJ performance occurred. Of the 4 CMJ PDFs identified only hip rate of power development was overloaded by the DJ and none were enhanced with training. The results imply that the pathway was effective in identifying whether DJ training would enhance participants CMJ performance. The model could be used to determine if a given exercise would enhance a specific group of athletes prior to initiating training.

KEY WORDS: performance diagnosis, exercise prescription, drop jump.

INTRODUCTION:

While a number of training exercises have been developed to enhance neuromuscular capacity, there are sometimes contrasting findings to their actual effectiveness. For example, plyometric drop jumps are commonly used to enhance lower extremity power and jump performance, and while a number of studies have reported enhancements (Gehri, 1998 ;Matavulj, 2001) others have found no enhancement (Young, 1999). Even where a group enhancement has been reported, individual participants may exhibit no enhancement (Gehri, 1998). This variation in findings may be due, at least in part, to the training exercise not effectively overloading the neuromuscular component that determines the given performance measure. Given that biomechanics is the scientific discipline concerned with understanding how the neuromuscular system is loaded and controlled, it has the potential to play a key role in improving the effectiveness of exercise training. In this regard, it may be possible to employ a biomechanical diagnostic and prescriptive pathway (Figure 1). Firstly, the factors that determine a given performance, referred to from here on as performance determining factors (PDFs), could be identified. Secondly, further analysis could establish whether or not a given exercise overloads these PDFs. If acute overload is present it could be hypothesised that the prescription of suitable training with this exercise should lead to an enhancement in the PDFs and performance. To the authors' knowledge such a pathway has not been fully applied or tested.

Identify the performance determining factors (PDFs) and rank their importance

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Establish whether, and the extent to which, an exercise overloads these PDFs

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Prescribe suitable training

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Aim: enhance PDFs

Aim: enhance performance

Figure 1: Diagnostic and Prescriptive Pathway for Identifying Effective Neuromuscular Training

In order to investigate the pathway described above, countermovement jump (CMJ) ability (jump height) was used as the performance measure of interest. The CMJ involves a preparatory movement downwards, flexion at the hip, knee and ankle, followed by vigorous extension of these same joints propeling the body upwards. While being evident in many sporting events, the CMJ is a relatively simple and well learnt task and its performance outcome (jump height) can be clearly and objectively defined. The plyometric drop jump (DJ) was used as the training exercise of interest. It involves stepping from a prescribed height and on landing immediately jumping upwards as high as possible and is an exercise commonly used to enhance CMJ performance.

The first stage of testing this model, and the aim of the present study, was to examine if the model could explain the enhancements, if any, in jump height associated with 8 weeks of DJ training from 30 cm. To achieve this aim it was necessary to:

(i) Determine the PDFs for the CMJ, and rank their importance

(ii) Examine what neuromuscular based kinetic and kinematic measures the DJ exercise overloaded, and the extent to which it overloaded the PDFs.

(iii) Determine if the enhancement in performance of the CMJ could be explained by the degree to which the PDFs were overloaded.

METHOD:

Participants: 34 physically active males (23 ± 4.0 yrs; 77.6 ± 9.8 kg) involved in a sport that employs vertical jumping participated in the study. Ethical approval was received by Dublin City University. All participants were injury free at the time of the test. They attended at least two familiarisation sessions where they were instructed on correct jumping technique.

Training: Four sets of 8 DJ (30 cm) repetitions 3 days per week for 8 weeks were carried out.

Data Analysis: Each participant performed 15 CMJs and 5 DJs from 30 cm both pre and post the training period. Participants placed their hands on their hips in both the CMJ and DJ in order to reduce the use of the arms.

Data Acquisition: Five reflective spherical markers were placed on anatomical landmarks on both sides of the body:- fifth metatarsal head, lateral malleolus, lateral femoral epicondyle of the knee, the bony prominence of the greater trochanter and the glenohumeral joint, each representing the joint centres of the toe, ankle, knee, hip and shoulder, respectively. A sixth marker was placed on the heel. A 12 camera VICON motion analysis system (VICON 512 M, Oxford Metrics Ltd, England) was used in conjunction with an AMTI force platform (BP600900, AMTI, MA, USA) and AMTI amplifier. Raw co-ordinate data and force data were used to calculate various joint and whole body kinetic (moments, power and work) and kinematic (angular displacements, velocities and their timing) measures.

Statistical Analysis: A group analysis (inter-subject), based on differences between individuals, was employed using the mean value for each individual's three highest jumps. Pearson product moment correlations were performed between the biomechanical parameters and the CMJ height to determine if the former were PDFs. Each CMJ variable that significantly correlated with jump height was entered into a forward stepwise regression. To determine if these and other variables were overloaded in the DJ, multiple dependent t tests were completed. In all analyses an $\alpha = 0.05$ level was adopted for statistical significance.

RESULTS:

There was no significant change in CMJ height following DJ training (pre = 41.7 ± 4.8 cm, post = 41.5 ± 4.4 cm). Eleven CMJ variables were significantly correlated with CMJ height (Table 1) and were therefore deemed the PDFs. These PDFs were then entered into a forward regression in order to rank their importance. Four statistically significant models were found (Table 2).

Of the variables that made up the 4 regression models, only whole body rate of power development was overloaded by the DJ. However, the gradient of the relationship between this variable and CMJ height was only 0.0003, indicating that even a relatively large increase in rate of power development would not notably improve jump height. None of the 4 PDFs present in the pre training regression models were significantly enhanced post training (Table 2).

Table 1 All Countermovement Jump Performance Determining Factors

Whole body kinetics and kinematics	Joint kinetics and kinematics	Temporal factors
1. Concentric work 2. Whole body rate of power development	1. Peak hip power 2. Peak knee power 3. Peak ankle power 4. Ankle concentric work 5. Hip rate of power development 6. Ratio of knee work at end of eccentric phase to knee work at start of concentric phase	1. Time between peak power and take off 2. Time between hip and knee joint reversal 3. Number 2 (above) normalized for concentric phase duration

Table 2 Regression Models Predicting Countermovement Jump Height

Model	Predictors	r value
1	Concentric work	0.61
2	Predictor 1 + Whole body rate of power development	0.8
3	Predictors 1 and 2 + Time between hip and knee joint reversal (normalized for concentric duration)	0.88
4	Predictors 1,2 and 3 + Time between peak power and take off	0.9

Table 3 Overload and Effect of Training on Selected Performance Determining Factors

CMJ PDF	DJ Overload	Change in PDF Pre Vs Post
Concentric work	No	No
Whole body rate of power development	Yes	No
Time between hip and knee joint reversal (normalized for concentric duration)	No	No
Time between peak power and take off (-VL)	No	No

Although not presented, the DJ overloaded a number of eccentric kinetic variables (power, work done) at the ankle and knee. These factors were not PDFs, but may clearly affect the magnitude of the same variables in the subsequent concentric phase [stretch shortening cycle; Bobbert et al (1996)].

DISCUSSION:

There was no significant improvement in CMJ performance following the 8 weeks of DJ training. These findings are similar to those found by Young et al (1999), but in contrast to several studies that have found DJ training to significantly enhance CMJ performance (Gehri, 1998; Matavulj, 2001). The question that this study now addresses, is why did no improvement in jump performance occur here and why do such contrasting findings occur? It is proposed that for improvement in performance to occur, the PDFs of the CMJ must be enhanced. However, none of the 4 PDFs included in the best predictor models of jump performance were changed with training and this may explain why jump height did not improve. The principle of training overload states that PDFs will be enhanced if they are overloaded with training. Our analysis found that only one of these 4 PDFs, whole body rate of power development, was significantly overloaded by the DJ. So why did this not improve with training? The measure of whole body rate of power development used in this study was dependent on hip, knee and ankle rate of power development. Rate of power development at the hip was improved significantly following DJ training yet there was no change at the knee and ankle. It is hypothesised that whole body rate of power was seen to be overloaded but was predominately due to overload at the hip. The improvement in hip rate of power development was not great enough to present as an improvement in whole body rate of power development.

An important question now is why have other studies found DJ training to be an effective exercise to improve CMJ performance? Firstly, different groups of participants are likely to exhibit different CMJ PDFs, due to differences in physical characteristics (anthropometrics, muscle fibre type, joint dominance etc.) and experiences (skill level, training history etc.). Secondly, for similar reasons, different groups are likely to experience different degrees of neuromuscular overload from the DJ exercise. We speculate that in those studies that found DJ training to be effective, the CMJ PDFs were overloaded by the DJ. It should be noted that 8 of the 34 participants in this study did improve their CMJ performance. This may be due to different individuals having different PDFs and experiencing different degrees of overload and enhancement from the DJ training employed in the present study. Group based analysis, as used in this study, may be masking these results (Bates, 1996). Therefore it may prove informative to undertake single subject and/or clustering based analyses to further develop the proposed biomechanical diagnostic profiling tool.

CONCLUSION:

Given that 3 of the 4 key PDFs were not overloaded and none of the PDFs were enhanced following DJ training, the diagnostic and prescriptive pathway seems to be effective in identifying whether DJ training would enhance CMJ performance. The application of this work for coaches and athletes could allow: (1) Identification of athletes, prior to training, who would have their PDFs overloaded and enhanced with the DJ exercise and who would therefore benefit from DJ training, (2) Manipulation of the DJ exercise in some way (e.g. increasing drop height or changing technique), to improve PDF overload and enhancement, and/or (3) Examination of other exercises, such as the squat or jump squat, that may overload the PDFs to a greater extent than the DJ. The model requires further testing, but it may allow for biomechanists, coaches and athletes to work together to increase the effectiveness of exercise training.

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