EFFECT OF SQUAT DEPTH ON VERTICAL COUNTER-MOVEMENT JUMP HEIGHT – A PILOT INVESTIGATION

Pui Wah Kong and Cheryl Xue Er Lim

Physical Education & Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore

The purpose of this study was to investigate whether a deep squat depth can improve vertical counter-movement jump height as predicted by theoretical models after a training period for neuromuscular adaptation. Five male subjects peformed a baseline test of vertical counter-movement jump performance using their normal and a deeper squat depths. Jump height was measured by the centre of mass displacement using a motion capture system. After that, they underwent three weeks of daily training (2 sets of 10 deep jumps) before returning for a post-test. Overall, subjects jumped higher in the deep compared with the normal positions on both days (pre-test: normal=52.8 cm, deep=55.5 cm; post-test: normal=55.8 cm, deep=58.3 cm). There were, however, large variations in individual response to training and squath depth.

KEY WORDS: neuromuscular adaptation, training, deep squat.

INTRODUCTION: The vertical jump height achieved in flight is determined by the impulse generated during the ground contact for standing jumps. Adopting a deeper squat position may potentially enhance jumping performance due to the longer time available for muscles to generate force. The influence of initial jump positions, mainly characterised by the degree of flexion at the hips and the knees, on vertical jump height has been investigated by a few simulation studies (Domire & Challis, 2007; Selbie & Caldwell, 1996; van Soest et al., 1994). Although theoretical modelling research suggest that the human body can jump higher if a deep squat position is adopted compared to a normal squat position, this prediction has not been supported by experimental studies on human subjects (Domire & Challis, 2007). The discrepancy may be related to subjects being inexperienced in squatting down to a deep position before the jump and therefore are unable to fully activate their leg muscles. This short coming associated with neuromuscular control can be addressed by conducting a longitudinal training study which provides sufficient time for subjects to be familiarised with the deep squat jump. Thus, the present study intended to clarify whether a deep squat depth can improve jump performance as predicted by theoretical models by incoporating a training period for neuromuscular adaptation. It was hypothesized that the deep squat position would be advantageous for vertical jump performance after training. The results obtained may provide important information for athletes, coaches, physical education teachers and exercise professionals to develop scientific training protocols for enhancing jump performance.

METHODS: This study used a pre-test, intervention and post-test design. The test protocols were approved by the Nanyang Technological Univeristy Institutional Review Board. Written informed consent was obtained from the subjects and/or their parents prior to the experiment. Five trained male subjects (mean (SD) age=21.2 (0.4) y, height=1.74 (0.05) m, mass=69.5 (14.5) kg) volunteered to participate. Subjects were naive to the expected outcomes of the study, and were asked to wear the same pair of shoes on both test days.
Subjects reported to the Sports Biomechanics Laboratory for a baseline test. Their body mass and height were measured. After a warm-up and familiarisation period, each subject performed six maximal effort vertical counter-movement jumps – three normal squat and three deep squat depths. The orders of the squat depth conditions were randomised, with two-minute rests between successive jumps. Prior to the jump, 34 reflective markers were placed on the subject for subsequent kinematic analysis (Figure 1). All jump performances

were recorded by an 8-camera three-dimensional motion capture system via the Cortex software (Motion Analysis Corporation).

(a) (b) (c)

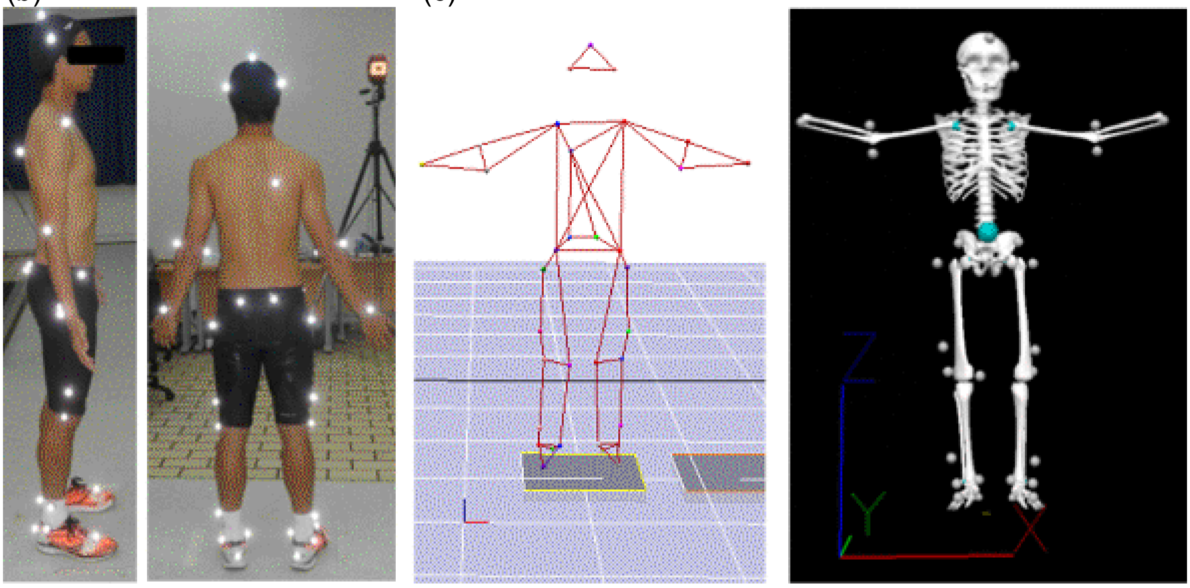

Figure 1: (a)Thirty-four reflective markers were placed on the subjects for motion capture via (b) the Cortex software and subsequent analysis in (c) Visual3D.

After the baseline test, subjects were asked to complete three weeks of daily training in their own time before returning to the laboratory for a post-test. Based on previous studies, a light daily training for three weeks was considered sufficient for the neuro-musculoskeletal adaptations to occur (Markovic & Mikulic, 2010). The training protocol involved two sets of 10 vertical jumps, with subjects touching the floor with both hands before jumping up (Figure 2). This training protocol aims to allow time for neuromuscular adaption for the deep squat position since subjects do not normally squat down low prior to jumping. Subjects were provided with a form to log their daily training record and report any issues such as injuries. On average, subjects committed 16 (range=8 to 20) training sessions and returned to the laboratory for post-testing in 21 (range 20 to 23) days. The jump orders for the post-test were kept the same as the pre-test. Other procedures were identical to those in the pre-test.

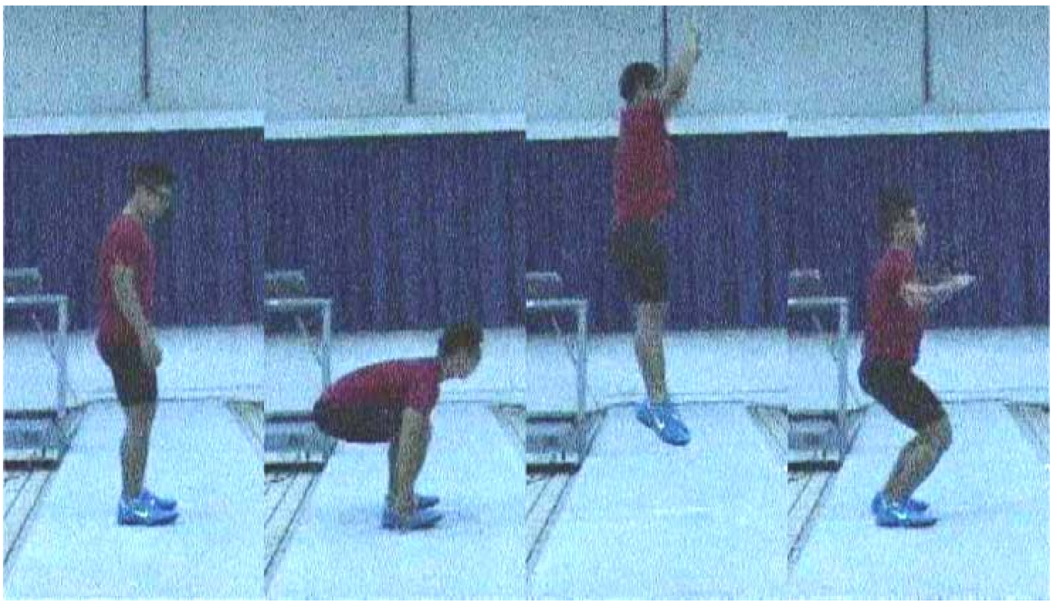

Figure 2: The training protocol involved two sets of 10 vertical jumps (hands touching the floor before jumping up) daily for three weeks.

From the 34 marker positions, a 13-segment model was constructed using Visual3D (C-Motion, Inc., Figure 1). The centre of mass (CM) vertical position, calculated from kinematic data, was identified at: 1) static quiet standing in a T-position, 2) lowest position during squatting, and 3) highest position during flight. The squat depth (CM standing – CM lowest) and jump height (CM highest – CM standing) were calculated subsequently. Individual and group mean (SD) data of the pre-test and the post-test in two squat depths (normal versus deep) were compared. No inferential statistical procedures were applied due to the small sample size in this pilot study.

RESULTS: On average, subjects squatted 15 cm deeper when they were asked to perform a deep squat jump (Table 1). Compared to the normal jump, subjects jumped higher by adopting a deeper squat position but the improvement appeared similar between the pre-test (2.7 cm higher) and the post-test (2.5 cm higher). After approximately 300 training jumps, subjects squatted down further and improved their jump performance in both normal and deep squat jumps (Table 1).

Table 1: Squat depth and jump height during normal and deep vertical counter-movement jumps before and after training.

Variables		Normal Jump	Deep Jump
Squat depth (cm)	Pre-test	37.0 (8.8)	52.8 (10.6)
	Post-test	41.0 (7.9)	55.2 (9.0)
Jump height (cm)	Pre-test	52.8 (11.3)	55.5 (11.6)
	Post-test	55.8 (10.0)	58.3 (12.2)

There are noticeable individual differences among the five subjects (Figure 3). Three subjects (S2, S4 and S5) jumped higher by adopting the deep squat position before and after training. One subject (S3) displayed higher jump height in the deep squat position only after training. One subject (S1) did not respond at all regardless of training, showing inferior performances in the deep squat jump on both test days.

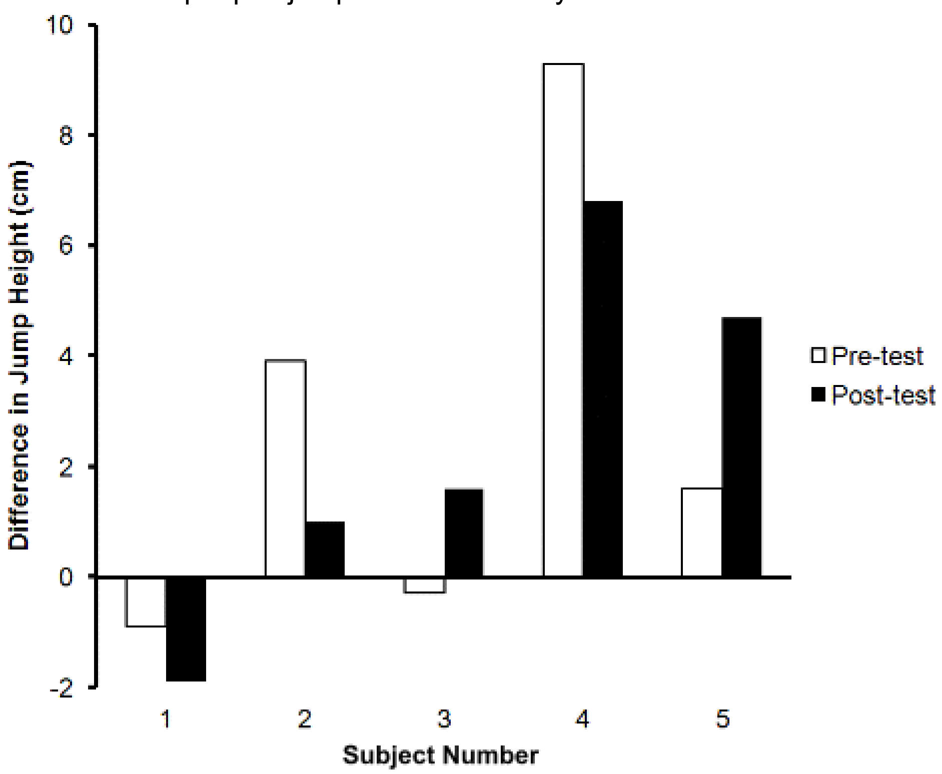

Figure 3: Individual subject responses in jump performance between the normal and deep squats jumps (difference=deep jump height – normal jump height).

DISCUSSION: The results showed that 4 out of 5 subjects jumped higher in the deep squat compared to their normal squat positions during vertical counter-movement jumps. Contrary to our hypothesis that a training period is needed for neuromuscular adaptation, the improvement in jump heights by adopting a deeper squat position was seen even at the baseline test in three subjects (S2, S4 and S5). This is somewhat surprising as Domire and Challis (2007) did not find any differences in jump height between normal and deep squat jumps. One explanation for the discrepancy is that we used counter-movement jumps which are more functional than the squat jumps used in their study. After three weeks of deep jumps training, both normal and deep counter-movement jump performances improved. There are, however, mixed responses to whether the training can bring along any additional benefits of the deep jump technique (Figure 3). While the 3-week training was effective for S3 and S5 to facilitate the neuromuscular control of the deep counter-movement jump, the advantage of the deep jump over the normal jump diminished after training in S2 and S4. S1 showed inferior performance when adopting a deeper position regardless of training.
We are currently expanding the sample size of the study. In addition, joint kinematics and kinetics will be further explored to better understand the mechanisms that enable an increase in jump height by adopting a deeper squat position.

CONCLUSION: This study illustrated the potential of using a deep squat position to improve jump height in vertical counter-movement jumps. It is unclear whether a training period for neuromuscular adaption is needed to demonstrate the benefits of adopting a deep squat position.

REFERENCES:

Domire, Z.J. & Challis, J.H. (2007). The influence of squat depth on maximal vertical jump performance. *Journal of Sports Science, 25*(2), 193-200.

Markovic, G. & Mikulic, P. (2010). Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. *Sports Medicine 40*(10), 859-95.

Selbie, W.S. & Caldwell, G.E. (1996). A simulation study of vertical jumping from different starting postures. *Journal of Biomechanics 29*(9), 1137-46.

van Soest, A.J., Bobbert, M.F. & van Ingen Schenau, G.J. (1994). A control strategy for the execution of explosive movements from varying starting positions. *Journal of Neurobiology 71*(4), 1390-402.

Acknowledgement: We wish to acknowledge the funding support for this project from Nanyang Technological University under the Undergraduate Research Experience on CAmpus (URECA) programme. Our thanks also go to Dr Qu Xingda and Mr Edwin Lam for their assistance in data collection.