CENTER OF MASS DISPLACEMENT DURING THE BADMINTON-SPECIFIC SPEED TEST

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The purpose of this study was to identify whole-body court movement strategies of elite badminton players when carrying out a badminton specific speed test. Twenty-one (12 male and 9 female) elite badminton players participated with whole-body kinematics collected using three-dimensional motion capture. Centre of Mass (CoM) total work and mean power over the whole test, and maximum and minimum CoM height were extracted. Genders were compared by t-tests and relationships between completion time and the investigated parameters were tested using Pearson correlations. Male players showed a higher lift and drop of CoM. A significant correlation was found among the male players between power and completion time. All male players exhibited greater power during the test than female players. The results illustrate a new way to quantify mechanical factors contributing to performance in badminton.

KEYWORDS: Badminton, performance, centre of mass, motion capture.

INTRODUCTION: Badminton is the world's fastest racket sport, with the shuttlecock often reaching resultant velocities over 100 m/s. Badminton is also characterized by multiple intense whole-body court movements consisting of high accelerations, decelerations, and quick changes of direction over short distances (Ooi et al., 2009). Selected badminton movements have previously been quantified by looking at the kinematics of players using 3D motion analysis. One of the movements that has been studied extensively is the forward lunge. Lunging forms an integral part of the movement repertoire of badminton players, making up 15% of all player movements during a match (Kuntze et al. 2016). Lunging allows the player to rapidly stop the forward progression of the body, form a secure base from which to play the shot, and move back into position to prepare for the next shot. In the fencing lunge, which may be considered similar to the badminton lunge, elite fencers decrease the height of their center of mass (CoM) more than novice fencers, to provide more stability. Moreover, they are capable of performing longer lunges (Gholipur et al., 2008). During the badminton lunge, healthy players exhibit a greater weight-shifting ability and higher maximum center of mass velocity compared to injured players (Huang et al., 2014). However, no other movements as part of the badminton game have received major attention yet.

Standardized speed and agility tests have previously been used to determine badminton specific player capacity. However, these tests have been accused of being too simplistic, not resembling the highly-specialized but complex movement patterns that characterize badminton. On this basis, a novel speed test for evaluation of badminton-specific movements (BST) was developed by Madsen et al. (2015). The test is designed to mimic match play with a sensor placed in each corner of the field, in which the player must perform 20 actions in a randomized order. The BST is sport-specific and can discriminate between different badminton skill levels. Elite players exhibit faster completion times than less-skilled and novice players.

From a mechanical point of view, it becomes important to identify how player behaviour can be characterized in regard to movement efficiency (Minetti et al., 1993). This may have implications for technique training, coaching and potentially even injury prevention. It was therefore the goal of this study to assess total mechanical work on the center of mass as observed during the BST. It was hypothesized that better badminton players were expected to have a faster completion time in the BST and that this relates to a movementpattern that minimizes mechanical work and results in higher peak velocity of the CoM. A significant difference was expected between male and female players in regard to these parameters.

METHODS: Twenty-one (12 male and 9 female) international elite badminton athletes with an age of 21.9 ± 3.4 years old (mean ± standard deviation), a mean height of 169.4 ± 24.0 cm and a mean mass of 64.5 ± 16.3 kg. All participants were part of Badminton Europe and trained at the Center of Excellence in Holbæk, Denmark. All participants signed informed consent. The experiment was approved by The North Denmark Region Committee on Health Research Ethics.
Whole-body kinematics were recorded using the Qualisys motion capture system (Qualisys AB, Gothenburg, Sweden). Fifteen Oqus 300+/700+ cameras were placed around the badminton court. A total of 62 markers were placed on anatomical landmarks using double-sided adhesive tape. The completion time was recorded using the BST microphones (Larsen Elektronik, Praesto, Denmark).
Participants performed one familiarization trial followed by four maximal effort trials in the BST. The badminton players were divided into three groups of eight, seven and six participants respectively. Within the groups, players were tested in a given order repeatedly to provide for sufficient rest time of >10 minutes between tests. The participants were instructed to perform the BST as fast as possible and were vocally motivated by the technical staff, coaches and team members. For each athlete, the fastest of the four completed trials was chosen as the person's best performance.

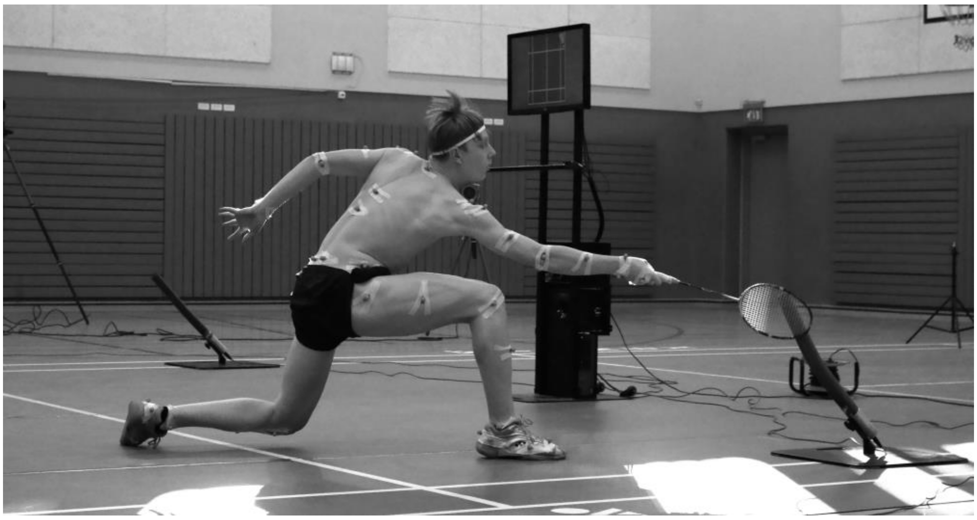

Figure 1: Participant during the BST when hitting the forehand front sensor.

The BST started in the center of the badminton court. A custom-made sensor (Larsen Elektronik, Praesto, Denmark) was positioned in each corner such that the player had to perform an overhead forehand or backhand shot, or a forehand or backhand lunge. A computer screen dictated which sensor the player should hit. After hitting a sensor, the player had one second to return to the center before the next position was displayed on a screen in front of the subject. Before the next position was shown, a countdown from 3 to 1 was displayed. The sequence of the movements was randomly assigned by a computer program (Direct RT 2008; Empirisoft Corporation, New York, NY, USA). The randomized sequence and the countdown were constructed to mimic real match situations.
The BST was completed when 5 actions to each sensor had been made resulting in a total of 20 actions. The BST performance was expressed in a total reaction time for all actions, from the time the visual cue was displayed to the moment the correct sensor was activated.
Markers were labelled, filtered at a cut-off frequency of 14 Hz, the resulting c3d file imported to Visual 3D (C-Motion Inc., United States of America) and a 15-segment full-body model applied to compute the center of mass position, using standard segment inertial parameters (Visual 3D). The height and velocity of the of the CoM were recorded and the height of the CoM at the static start position was subtracted (Figure 2, showing an illustration of the maximum and minimum CoM height). The change in potential and translational energy was

calculated frame by frame then summed over time to estimate work on the CoM over the whole movement time. Mean external power was estimated dividing CoM work by time used to complete the BST. Work and power were expressed in relation to body mass.

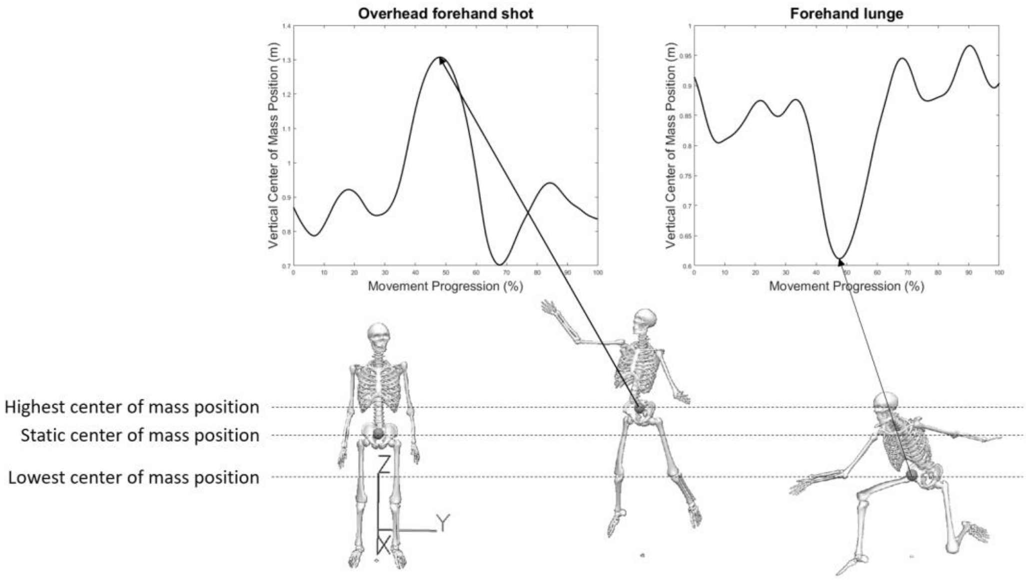

Figure 2: Illustration of body model and CoM analysis.

The relationships between test completion time and range of CoM movement and mean external power on the CoM were tested with Pearson Correlations. Gender differences were tested using t-tests.

RESULTS AND DISCUSSION: The results showed a significant difference between male and female players for range of CoM lift (0.67±0.05 m vs. 0.42±0.04 m; p=0.001) and total work (3.49±0.06 kJ/kg vs. 3.08±0.1 kJ/kg; p=0.007), respectively. These differences may be caused by the gender specific heights of the microphones. For male players, the sensors on the back line are 50 cm and 25 cm higher on the forehand and backhand side than for female players, respectively. Consequently, male players must jump to reach the forehand sensor, while female players do not have to jump. More energy is needed to jump and therefore the total energy demand is higher for male players. A significant correlation between male players' completion time and mean external power (R=0.714, p=0.009) was also present when analysing all movements individually. This was not the case for female athletes which suggests that faster male players need less energy to achieve better results. However, the cause for this correlation is unknown but is likely to be related to the acceleration and deceleration profile of the CoM which is influenced by movement technique. The present data set will be used to explore which technical aspects may characterize an efficient movement pattern, which would have implications for coaches. In this research only the external work was computed. It is recommended that internal work is also included, as this might influence the relationship between test completion time and energy consumption because internal work constitutes 25-40% of the total mechanical work in humans. Eventually, metabolic energy consumption should also be measured to confirm a relationship between test completion time and movement efficiency.

CONCLUSION: This research demonstrated the potential of motion capture technologies in badminton. It is the first time that kinematics of so many international elite badminton players have been analysed and correlated with performance. However, only a correlation between test completion time and total average power generated by the center of mass for male players has been identified. For these results to be meaningful in badminton training and coaching, it is of importance that novice and less skilled players are also tested and included in the correlation analyses. This would strengthen the relationship, as well as provide more insight into the reasons behind this correlation. In addition, multiple regression can be performed to investigate whether a combination of different variables can predict BST completion time.

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