A Discussion - Integrating Sports Science Disciplines of Biomechanics and Strength Training in the Teaching of Table-tennis Drives - An Example in Singapore Sports School Experience

論文 — 並用運動生物力學與體能學在於乒乓拉球指導 — 新加坡體育學校經驗之談

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Abstract

The Singapore Sports School was formed in 2003 as the result of a government initiative to strive for a sporting nation. With this emphasis on sporting success, the integration of sports science in the development of young athletes is a core strategy used in the teaching and coaching pedagogy of the sports school. The purpose of this article is to highlight an example of such a strategy used in teaching table-tennis skills. Specifically, our example will feature an integration of the disciplines of sports biomechanics, strength and conditioning principles and table-tennis coaching pedagogy, as a framework for coaching specific aspects of table-tennis forehand and backhand drives; and, draw implications of such an approach for use in sports programmes of schools in general.

摘　要

新加坡體育學校成立於2003年，是政府邁向運動之國目標的其中一個主要計畫。因此，這篇論文主要描述怎樣運用運動科學在於乒乓技術的進展。它內容將讓你能進一步瞭解如何運用運動生物力學與體能學在乒乓拉球與及其它運動方面。

Introduction

Completed in 2004, at a cost of SGD $75 million, the Singapore Sports School has on-site sports science and rehabilitation facilities as well as modern training amenities. The school received its first intake of 13-14 year old athletes in seven core sports identified by the Ministry of Community, Youth and Sports (MCYS) of the Singapore Government. The sports were badminton, bowling, sailing, swimming, table-tennis and track and field. In 2005, it has included golf.

At the 2004 Athens Olympics, Singapore achieved a milestone in its sporting achievements, in the women's individual table-tennis event. Our local sportswoman, Li Jia Wei emerged fourth. (ESPN, 2004). This provided a huge impetus and interest in the sport of table-tennis, locally. At the Singapore Sports School, a scientific framework for developing the skills of the young athletes in table-tennis was initiated. As a preliminary endeavour, the focus was to develop the fore-hand and back hand drives of the sport. These skills are fundamental developmental movements in table-tennis. Coaches typically spend much time developing these techniques in developmental athletes (Seemiller and Holowchak, 1997). However, previous work on table-tennis forehand (Chen and Cai, 2001; Wang, 2001; Zhang, Ma and Guan, 1998) or on hitting and catching skills (Savelsbergh and Bootsma, 1994) while having provided insight into the skills, have not been cross-disciplinary in nature, with little or no attempt to discuss strategies for developing such skills particularly in young athletes. Therefore, an integrated approach will greatly benefit the understanding of the technique and provide a systematic and holistic development process for young athletes so that their playing careers will be extended. Developmentally appropriate training strategies are keys to minimizing injuries. These strategies take into account the individual abilities both cognitively and physiologically (Koh, 2005). Also the methods of training used are based on science and not on guesswork or trial and error. Thus, this article is an attempt by the collaborators to showcase an integrated sports science approach that has the potential to be applied across sports training and in the teaching of PE or sports in schools. In particular, we will show how a template model can be established for qualitative analysis in coaching.

Methods

Ten developmental table-tennis players (12-14 year olds) were involved in the study. The players were video-taped using a 50 Hz Panasonic 3CCD camera which was placed such that the plane of action of the trunk and right leg was at right angles to the optical axis of the camera lens. The players were required to hit a continuous stream of table-tennis balls using either the fore-hands or the back-hand stroke and reversing the practice subsequently.

The kinetic link sequential segmental movements of the leg, trunk and drive arm were the main contributors to the vertical and horizontal components of the drive (ETTA, 2002). These movements could be quantified in terms of the angular displacements of the respective segments. The key elements of both drive techniques were identified by the coach and biomechanist as the following:

a) knee extension;
b) hip extension;
c) trunk rotation;
d) arm drive in anterior direction; and,
e) external rotation of forearm (wrist snap movement).

These key elements identified contributed to the vertical and horizontal motion of the ball, as well as, the spin of the ball. Although there are numerous key elements, our endeavour focused only on the 2-D analysis of the hip and knee extension to provide a framework from which future qualitative analysis can be based upon. In this article, we focus on the knee and hip extension of the technique of the drive. The analysis is done based on good drives defined as those shots that are hit successfully over the net and onto the opponent's end of the table.

Knee Extension

In a closed kinetic chain, the feet are anchored to the ground (Ellenbecker & Davies, 2001) During knee extension, assuming the shank remains stationary due to co-contraction of the muscles about the ankle joint and that the hip angle remains unchanged, the body's centre of mass (CM) will be propelled forward and upwards (Figure 1). This results in a loss of stability if the body's weight falls outside of the base. As a consequence, knee extension is followed by hip extension so that stability is restored.

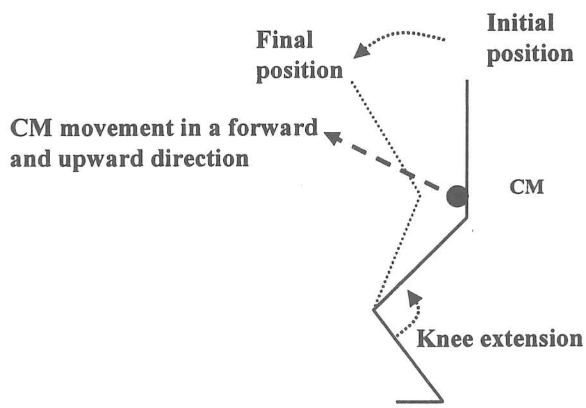

Figure 1. Schematic of trunk cum CM movement due to knee extension while maintaining joint angles at the hip and ankle.

Hip Extension

By the same analogy, hip extension, while keeping the joint angles of the lower limbs unchanged, will propel the body's CM upwards and backwards (Figure 2). This shifts the body weight back into the base of support especially if hip extension accompanies the knee extension sequentially.

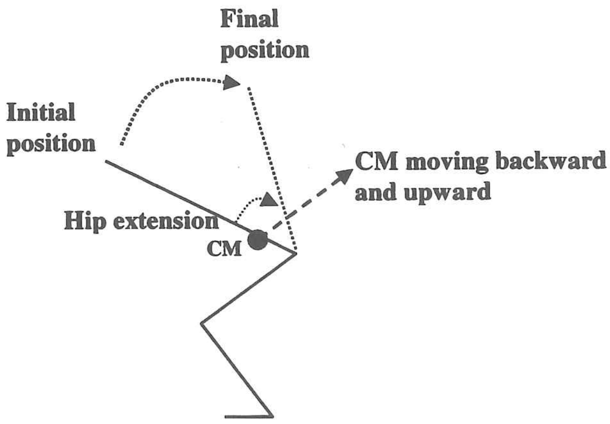

Figure 2. Schematic of CM movement due to hip extension while maintaining joint angle configurations of lower limb segments

The consequence of the sequential knee and hip extension is an increase in the vertical velocity of the body and thence the ball by transfer of momentum. To aid in the coaching of the drive techniques, the key elements were categorized according to the extent of joint movement in Table 1. This provides a qualitative analysis template from which feedback can be provided and reference drawn to visual images for illustration, to help the athletes understand what is required, what errors they are committing and thence be better able to make technique modifications. The computed angles were derived using simple 2D geometry with a known calibration scale. The joint angles were obtained from digitizing based on an average of five trials per athlete per drive technique. The starting position of the drive was defined as the position at the end of the counter-movement squat action of the player; the end position being the instance the bat makes initial impact with the ball.

Table 1. Categorizing the Extent of Joint Angular Displacement to Facilitate the Feedback Process.

Extent of movement	Knee(o) extension	Hip(o) extension
Small (S)	<20	<20
Typical (T)	21 to 79	21 to 69
Large (L)	>80	>70

To provide an inter-disciplinary focus, recommendations on strength and conditioning were incorporated based on the anatomical analysis of movement with the strength and conditioning coach. This is an important area of development as strength training is paramount in achieving sports excellence and remains integral part of an athletes' preparation (Jones, 1998). From an anatomical perspective, the muscles involved in these actions are the quadriceps for knee extension and the erector spinae muscles for back extension (Floyd & Thompson, 2001). Details of the conditioning programme will be discussed later.

Results

Individual variation of technique among the athletes may be expected. However, it is nevertheless important to determine to what extent the techniques vary. The use of a categorization template allow the coach and athlete to have a quick overview of the main differences in technique used to achieve the forehand and backhand drives. As an overview, Table 2 summarizes the number of individuals using the various extent of joint actions.

Table 2. Athlete's Knee and Hip Joint Extension based on Categories defined in Table 1 for the Forehand and Backhand Drives (n=10).

Drive technique	Knee Extension			Hip Extension		
Joint movement categorisation	S	T	L	S	T	L
Number (forehand)	1	7	2	7	3	-
Number (backhand)	2	6	2	4	4	2

Also, the relationship of the joint action with respect to the horizontal and vertical components of velocity are shown in Table 3. From Table 3, we note that the principal contribution to ball velocity as a result of knee and hip extension is in the vertical component. This is essential for the flight trajectory of the ball since it has to clear the net barrier midway through the table.

Table 3. Correlation of the Joint Actions to Horizontal and Vertical Velocity in Table-tennis Forehand and Backhand Drives.

Key elements	Relationship with velocity components
Knee extension	(r = 0.89 with vertical component)
Hip extension	(r = 0.79 with vertical component)

Discussion

In both drives, the aim is to hit the ball forward and upwards to provide the ball with initial forward and upward momentum. This is important so that the effect of gravity does not cause the ball to travel into the net barrier. Other aspects of the motion of the ball such as ball spin arising from the arm and wrist actions are acknowledged but are not the focus of this article. It was observed that the combined effect of hip and knee extension result mainly in vertical motion. Therefore, any contribution to horizontal ball velocity must be due to trunk rotation and arm horizontal adduction. Wrist actions introduce spin to the ball. The implication to the athlete, therefore, is to maximize on trunk rotation and arm horizontal adduction for a good flat drive. However, this is subject to sufficient vertical velocity. Hence the knee and hip extension was analysed to determine if the athletes were producing sufficient velocity in this direction for the ball to pass over the net. From this analysis, a qualitative analysis template on hip and knee extension was derived to help coaches provide timely and objective feedback.

The majority of the players produce knee extension in the "typical (T)" category 2 (21-79 degrees) for both drive techniques. However, hip extension is small (<20 degrees) for the forehand drive in majority of players; and evenly split between categories "S" and "T" for the backhand drive. The latter may be due to technique variations due to the relative statures of the players. With this template, the coach can for example, determine if a lack of knee extension (category S) or too much of it (category L) is causing the ball to fly into the net, or going past the table-top. This feedback can be provided to the player for technique correction immediately. This template can be extended to analyse the extent of trunk rotation or horizontal abduction of the arm for the key elements contributing to horizontal ball velocity.

Recommendation for Strength and Conditioning

A full anatomical analysis shows the following joint actions: a) internal and external rotation of the shoulder joint; b) wrist flexion and extension; c) arm horizontal abduction and adduction; d) trunk flexion and extension; e) hip rotation; f) knee flexion and extension. Knowledge of the relative joint motions can guide the coach and athletes in implementing appropriate conditioning programmes to develop their strength and endurance appropriately.

A strength and conditioning program (Table 4) was planned consisting of a meso-cyclic training phase of 12 weeks duration (Bompa, 1999). In planning the conditioning programme, the game requirements were considered specifically for developmental athletes in the preparatory phase of the training cycle. The conditioning exercises mirror the movement patterns of the sport (table-tennis). The program was performed every alternate day (2-3 per week) for the duration of the 12 week preparatory period. Stacked weights were used instead of free weights to enhance the level of safety for the developmental athletes.

Table 4. Strength and Conditioning Program for the Developmental Table Tennis Players for One Meso-cycle.

Weeks	Sets and Repetitions	Focus
1-4	2x15	Developing good lifting technique and basic conditioning
5-8	2x12	Endurance
9-12	3x10	Strength and endurance

Exercises: 1. Leg press; 2. Roman Chair Extension; 3. Cable Trunk Rotation; 4. Rotator Cuff: a. External rotation - from neutral; b. Internal rotation - from neutral; 5. Wrist abduction and adduction

The weights selected were such that fatigue was induced after the final repetition of a set. If an athlete was capable of completing an extra two repetitions with the selected weight, then the weight lifted was increased. Moderate increment of load over time ensured workouts remained progressive (Murphy, 1998). The focus of the conditioning programme ranged from familiarization and developing proper lifting techniques initially; to building endurance; and, finally developing strength, as the number of repetitions diminished. This was implemented to guide developmental table-tennis youths during the early stages of a training cycle. It outlines fundamental exercises which trains those muscles involved in table tennis specific movements. It is to be noted that the aim of this preparatory phase is to emphasize proper training and lifting technique and minimize muscle imbalances through muscular endurance and strength work.

Figure 3 shows an example of the knee extension exercise (Leg press).

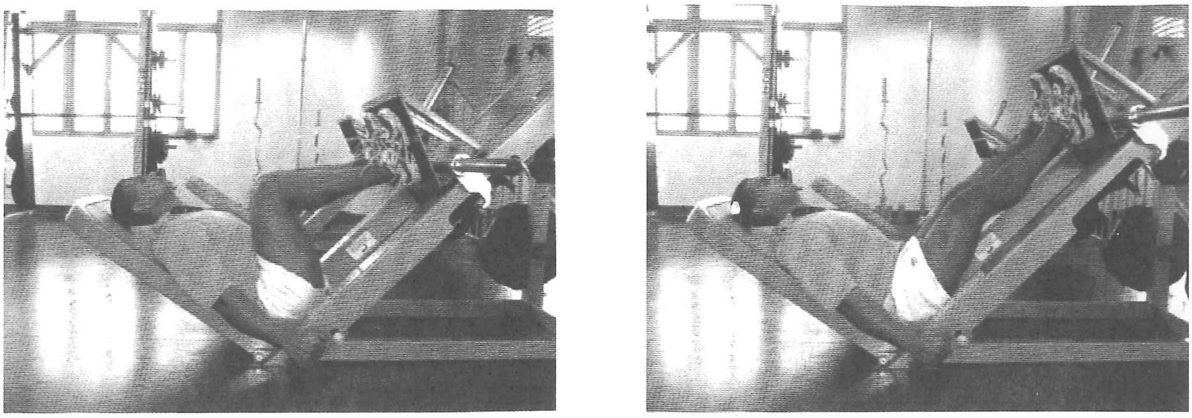

Figure 3. An example of the knee extension exercise (Leg press). Place foot at centre of foot plate and shoulder width apart. Release support locks and slowly lower down the weight with control. The weight should be lowered until a 90 degree angle at the knee joint. Straighten the legs to return to the start position. Do not rotate the knee in or out and keep it in line with the feet.

There is also the element of specificity between the strength work and table-tennis drive actions. To aid neural adaptation, the athletes also practiced the drive techniques at the end of each set for 5 minutes before returning to the next set. This is done by shadowing the movement in front of a mirror.

Conclusion

This article has highlighted an attempt to integrate sports science in the training of young developmental athletes with the example of the forehand and backhand drive in table-tennis. The kinetic link of the relevant segment contributions to ball velocity was identified with insights gained into the respective contributions of the joint actions to the horizontal and vertical component of ball velocity. By categorizing the extent of joint motion of the knee and hip, we are able to use the template to highlight technique deficiencies to the athletes quickly and visually, when there is insufficient or too much vertical ball velocity. An appropriate conditioning programme was developed taking into account principles of training and the training cycle. No coach operates independently. They are increasingly reliant on the support of sports science that relays critical information and data about the athlete, so that coaching becomes more relevant in meeting individual needs. Training methods have thus become sophisticated and meticulous (Bompa, 1999). Table tennis is no different. There is an ever increasing need for players to reach outstanding levels of performances. It has become more imperative as Singapore embarks on the quest for sporting recognition. The ability to achieve positive results are dependent on a well thought training plan which is scientific, progressive and cyclic. This integration of sports science disciplines can easily be modified and adapted to suit different sports techniques and applied in school sports coaching settings with an emphasis on holistic and scientifically based, developmentally appropriate training methods. By breaking down a skill to its specific key elements, a coach or PE teacher can consider using a skill analysis template to provide feedback to athletes. The quantification of measures can be obtained using simple 2-D analysis motion analysis software such as Silicon Coach or Dartfish. Such make-easy software facilitates video capture for feedback (Koh and Anwari, 2004). By analyzing the technique, the coach or PE teacher can also introduce strength and conditioning interventions that will ultimately enhance athletic performance of the individual.

References

Bompa, Tudor (1999). Periodization: *Theory and Methodology of Training (4th ed.).* Champaign, Illinois: Human Kinetics.

Chen, J., & Cai, J.L. (2001).Research on feasibility and technical characteristics of pen hold grip four-side-attack. *Journal of Beijing University of Physical Education (Beijing), 24* (2), 254-257.

Ellenbecker, T.S., & Davies, G.J. (2001). *Closed Kinetic Chain Exercise.* A comprehensive guide to multi-joint exercise. Champaign, Illinois: Human Kinetics.

English Table Tennis Association (ETTA, 2002). *Know the game: Table Tennis. (3rd ed.).* Hong Kong: A & C Black.

ESPN (22 August 2004). *Singapore's fourth-place finisher left in tears.* At http://sports.espn.go.com/espn/print?id=1864884&type=story. Retrieved on 10 Dec 2004.

Floyd, R.T., & Thomson, C.W. (2001). *Manual of Structural Kinesiology (14th ed.).* Singapore: McGraw Hill.

Koh, M. (2005). *Our world through GymFlash!.* Singapore: Icon Books.

Koh, M., & Anwari, K. (2004). Integrating video and computer technology in teaching - An example in gymnastics initial PE teacher-training programmes in Singapore. *British Journal of Teaching Physical Education, 35*(3), 43-46.

Murphy, Lindy (1998). *Train for Success.* Victoria, Australia: Bouquet Productions.

Savelsbergh, G.J., & Bootsma, R.J. (1994). Perception-action coupling in hitting and catching. *International Journal of Sport Psychology (Rome), 25*(3), 331-343.

Seemiller, D., & Holowchak, M. (1997). *Winning Table Tennis. Skills, Drills and Strategies.* United States: Human Kinetics.

Wang, W.P. (2001). Research on the new method of forehand fast drive. *Journal of Physical Education (Guangzhou, PRC), 8*(3), 37-39.

Zhang, Z.;Ma, G., & Guan, Y. (1998). Characteristics of neuro-regulation in elite table tennis players). *Chinese Journal of Sports Medicine (Beijing), 17*(3), 200-205.

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