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REVIEW

Development of Badminton-specific Footwork Training from Traditional Physical Exercise to Novel Intervention Approaches

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ABSTRACT

Background: Badminton has been one of the most popularised sports and physical activities around the globe with documented healthy benefits. Training of badminton footwork could enable rapid movement velocity thus improving the athletic performance. This study was aimed to review the development of badminton footwork training and summarise the different exercise training approaches and resistance training.

Methods: A systematic search of "badminton footwork" and "exercise training" was conducted in the research articles of both English and Chinese languages in order to review the development of badminton sport, footwork classification and definition, traditionally employed exercise training, and resistance training.

Findings and Implication: A recent popular exercise training intervention, wearable resistance (WR) training, was mainly introduced and discussed as this approach has been successfully employed in the training of other sports. Being a typical acyclic motion on badminton court, the training of badminton footwork shall consider integrating the WR approach with wearable and adjustable loads. The training intervention may attach incremental loads to either the whole body or regional limbs to practice real-competition movements with high-velocity, thus forming motor adaptation. The adaptation from task-specific training may increase footwork efficiency and transfer to match situation. Future WR research should compare different WR loading configurations from acute and longitudinal analysis, thus forming scientific evidence to support selection and design of training scheme for badminton footwork. Findings may provide implications for the selection of approaches and schemes design for badminton-specific footwork training to improve on-court performance and prevent potential injuries.

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1. INTRODUCTION

Badminton is a sport involving hand grasping a racket to hit the ball (called shuttlecock in badminton) over a net in the middle court. This sport often involves two "singles" players (with one player in each side of the net on court) and/or four "doubles" players (with two players in each side of the net on court). The sport had a history of over 2000 years and modern badminton was firstly developed at around 1850s. The sport of badminton was firstly included into Olympic event in the 1992 Barcelona Olympic Games (Valldecabres, Casal, et al., 2020).

Badminton, as one of the most widely played sports in the world, attracted over 30,000 registered athletes from 169 countries or regions to participate in the international competitions or tournaments around the world, as reported from the Badminton World Federation (https://bwfbadminton.com/players/, accessed on the August 20, 2022). There are also millions of recreational badminton participants due to its popularity (Lam et al., 2020; Phomsoupha & Guillaume, 2015) and reported healthy benefit with significantly reduced risk of mortality (Oja et al., 2017).

Being the fastest racquet sport, badminton requires complex coordination of the muscular control and work (and power) output to facilitate the execution of movements (efficient footwork to move into a best location on court and handwork to hit/return the shuttle) (Barnamehei et al., 2020; Cronin et al., 2003; Lam et al., 2020; Lin et al., 2007). Specifically, this sport requires a high fitness level with comprehensive skills of motion speed and agility, endurance and stamina, strength and power, and delicate hand skills and racket touches for precision shuttlecock return (Fernandez-Fernandez et al., 2013). What else, due to the passionate and enthusiastic spirit in this sport, badminton players, either elite athletes or novice amateurs, are aimed to improve their skills and techniques. However, the badminton players of junior-level watched the recorded game video of the world-top athletes to study, analyze and imitate the movement skills (i.e., net shot, net lift, net kill, back-court clear, drop shot, and smash, etc.), with primary attention paid to the techniques of handwork (Torres-Luque et al., 2020; Valldecabres, Casal, et al., 2020).

The badminton footwork was investigated recently to foster the improvement of performance and prevention of injury (Lam et al., 2020; Lee & Loh, 2019), as rapid moving into the right position on court would enable shuttlecock return with high-quality. Both handwork and footwork combined thus formed a comprehensive understanding of this sport (Phomsoupha & Guillaume, 2015). Specifically, the attributes to badminton lunging footwork were analyzed (Lee & Loh, 2019), and biomechanical characteristics of lunges were reviewed from perspectives of athletic-level, footwear effect, and lunging directions (Jiang, 2020; Lam et al., 2020). Furthermore, the influence of fatigue (reduced muscular fitness and condition) was found to link with increased risk of injuries (Herbaut & Delannoy, 2020; Xiang et al., 2022; Xu et al., 2022), reduced anticipatory performance (Alder et al., 2019) and loading accumulation (Yu et al., 2021) in the lower extremity.

Thus, this study is aimed to review the development of badminton-specific footwork training, covering the traditional exercise training, resistance training and wearable resistance intervention as a novel approach. Findings may provide implications for the selection of approaches and schemes design for badminton-specific footwork training to improve on-court performance and prevent potential injuries.

2. DEVELOPMENT OF BADMINTON SPORT TRAINING

Human motor system is a complex involving with physiology and neurology, primarily involving musculoskeletal, nervous, cardiovascular, respiratory and endocrine systems (Al-falahe & Vallbo, 1988). The chief command is controlled by the nervous system, and the directional signal is transferred to the musculoskeletal system (human motion is manifested with muscular contraction to pull the skeleton around the specific axis of joints). Basically, the human motor system consists of three organs: bone, bone junction and skeletal muscle. Bones are connected together in different forms, which then become the basic shape of human body and provides attachment for the muscles. Under the innervation, the muscles contract and pull the attached bones, and take the movable bone connection as the hub to produce lever movement (Asmussen et al., 2018).

The training of badminton specific tasks, such as on court footwork and other movements, may need to consider the gender-based aerobic and anaerobic capacities in male and female athletes (Y. Fu et al., 2021), fatigue effect on injury risks (Herbaut & Delannoy, 2020; Valldecabres, Richards, et al., 2020), athletic level (or performance) based (Barnamehei et al., 2020; Mei et al., 2017), and physiological load and biomechanical impact (Alder et al., 2019; Yu et al., 2021).

BADMINTON FOOTWORK

Footwork is an interpretation of the moving direction, and speed of footwork will improve the real-match on court athletic performance (Lin et al., 2007; Valldecabres, Casal, et al., 2020). Footwork of court sport was the key movement method used to choose a right position, which generally composed of four links, starting, moving, braking, and returning. The '*starting*' is a process of moving from a relatively stationary stance to the shuttle, which is based on the judgment and reaction. The 'moving' generally refers to the displacement process from the center position to the hitting position. The 'braking' is the inertia of holding the movement after being in place, keeping the weight of the body steady, to assist finishing actions. The 'returning' is to move back to the center as soon as possible after finishing the shuttle and prepare for the next movement. Tang (1988) reported that footwork was composed of many single steps that varied in different ways. According to the trajectory of the shuttle, the way of batting, and the continuous changes in strategy and tactics, the footwork was based on different needs thus showing different combinations. A complete set of footwork typically starts first and then hit the shuttle as per the demand (W.-J. Fu et al., 2009).

Badminton footwork refers to the fast, reasonable, and accurate mobile method adopted by athletes on the court to move into the appropriate position in the badminton competition. Xiao (2005) reported in badminton teaching and training that badminton athletes were moving forward in the last step while pushing back to the ground at the same time. The other foot took a big step in the direction of the shuttle to the position of each hitting location. The footwork of hitting the shuttle was called badminton pedaling step by step.

Based on the different moving directions, badminton footwork on-court is divided into three parts, '*Net-accessing*', '*Back-off*', and '*Side-stepping*'. While according to the on-court location, footwork could be divided into the frontcourt steps, the midcourt steps, and the backcourt steps. Specifically, the frontcourt net footwork represents the method of moving the shuttle on the net or by taking off to a higher position. The midcourt footwork mainly includes footwork in the midcourt when the opposing players smashed the shuttle, the footwork and the move of the 'fish-jump' through the take-off and landing. The backcourt footwork generally includes the footwork of backward catching the shuttle when the shuttle reaches the high court in the backcourt and the take-off in the backcourt. While moving in the whole court, the footwork should be adjusted based on location of the hitting distance and the distance between the shuttle and player. The combination of steps, such as stepping, striding, jumping, padding, and crossover, typically requires 1 to 3 steps of the unequal step and thus quickly reached the position to hit the shuttle (Torres-Luque et al., 2020; Wei et al., 2009).

BADMINTON FOOTWORK TRAINING

Sport and exercise training includes the common principles of universal significance from the training practice of many special projects. These basic theory and principles could be employed to deeply explore the sports training practice that has not been recognized and understood by people. Sport and exercise training widely absorbs the theories and methods of modern scientific and technological achievements and multiple courses, which could be applied to the theoretical research and practical application of sports training and the basic theory of general sports training to guide various training practices (Hoffman, 2002).

Specifically, "*Pattern training method*" is a control method to organize and grasp the process of sports training according to the requirements of highly representative normative goal model. "*Program training method*" is a method to compile a variety of training contents into training procedures orderly and logically. According to the timing of the training process and the systematic characteristics of the training contents, training activities are organized as per the predetermined procedures, and implement scientific control over the training process. "*Decomposition training method*" refers to the method of reasonably dividing the complete technical action or tactical cooperation process into several links or parts, and then training according to links or parts.

"*Complete training method*" refers to the training method of complete practice from the beginning to the end of technical action or tactical cooperation, regardless of parts and links. "*Repetitive training method*" refers to the practice method of repeating the same exercise for many times and arranging relatively sufficient rest between the two exercises (Y. Fu et al., 2021). "*Continuous training method*" refers to the training method with low load intensity, long load time and continuous practice without interruption. "*Transformation training method*" refers to the training method of changing exercise load, exercise content, exercise form and conditions to improve athletes' enthusiasm, interest, and adaptability. "*Circular training method*" refers to the training method that sets the practice means to several practice stations according to the specific tasks of training, and the athletes complete the practice tasks of each station in turn according to the established sequence and route. "*Competition training method*" refers to the method of training according to the rules and methods of competition under approximate, simulated, or real and strict competition conditions (Chen, 2014; Y. Fu et al., 2021; Mcguigan et al., 2006).

3. RESISTANCE TRAINING

Resistance training is one commonly employed way of strength training, which is usually referred to as the process of overcoming resistance to achieve muscle growth and power increase. Resistance training is a key part of comprehensive physical exercise. This exercise can significantly increase muscle strength and volume and play a role in the prevention and treatment of chronic diseases. The contents of resistance training exercise prescription mainly include training intensity, group number, frequency, mode, sequence, intermittent time, muscle contraction speed, and training volume. Resistance training should be gradual, different from person to person, the comprehensive exercise of main muscle groups, guarantee enough strength and quantity to increase muscle strength, endurance and maintain fat-free body weight (McQuilliam et al., 2020).

The following consideration should be paid during exercise training, that should (1) include resistance training equipment, free weight, and exercise of their own weight; (2) train single-joint exercise and multi-joint exercise; (3) follow the principle of comprehensive exercise, carry out multi-joint and multi-angle exercises, mainly by dynamic exercise. Resistive motion can be divided into static (isometric) and dynamic (isokinetic and isokinetic) contractile activities. Dynamic contraction can be divided into resistance training with fixed load and variable load, which could be used to increase muscle strength, endurance, and cause different adaptive changes in muscles (Rodrigues et al., 2020).

The positive effect of resistance training on athletic performance was extensively reported thus being employed in exercise training, while it should be noted that the increase in muscle strength induced by resistance training may not usually be attributed to the activation of the neuromuscular system rather than the physiological structure of the muscles. At the same time, there is little direct evidence that this increase in muscle strength could lead to an improvement in athletic performance. Sport scientists usually employ muscle performance tests such as horizontal jump, vertical jump, and sprint results to evaluate muscle strength changes because these evaluation tests are simple, easily performed and relatively inexpensive. One key certainty was that both traditional strength training and resistance training would play a positive role in improving athletes' strength and ultimately improve the sports (Harries, Lubans, Callister, 2012).

4. WEARABLE RESISTANCE TRAINING

Recently, the new progression in materials manufacturing and training technology with specialized base garments forming the innovation in WR training, for example, the Lila Exogen exoskeleton suit and Titin Tech weighted compression vest (as presented in the Figure 1). These developments have enabled more load/weights to be attached directly to the human body, and greatly increased the flexibility of WR loading placements and magnitude, which enables much greater customization of load magnitudes, orientations, and locations around the body (Macadam, Cronin, et al., 2017).

The wearable resistance (WR) training via attaching external mass to the body trunk and/or segments was proposed to modify the moment of inertia for the purpose of training with WR intervention for the movement specificity (Macadam, Cronin, et al., 2017). The principle was to stimulate the neuromuscular system with greater loadings to generate larger output of

Figure 1 Illustration of compression vest, pant, arm and leg sleeves with attachable loads.

strength and power (Rodrigues et al., 2020). Several promising efficacies in altering the output of mechanical power and energetic consumption were reported in the activities of running (MacAdam et al., 2019a), sprinting (Macadam et al., 2020, 2021), jump-landing (Macadam, Simperingham, et al., 2017), golf-swing (Macadam et al., 2019b), and soccer turning (Rydså & van den Tillaar, 2020) with WR loadings up to approximately 10% body mass (BM). As indicated in the above literature, most activities were cyclic motions (i.e., running and sprinting). Whilst the influence of WR on the acyclic motions were scarcely investigated, which was proposed as one future research direction (Macadam, Cronin, et al., 2017).

While considering the typical and acyclic lunging step, commonly practiced in sports of badminton, fencing and squash (Lees, 2003), this motion involved the limbs of the unilateral side (Yu et al., 2021). Lunge took over 15% of badminton footwork (Kuntze et al., 2010), and quickly execution of a lunge and return to the base position or another direction is critical for badminton shot (Cronin et al., 2003; Mei et al., 2017). This specific motion required certain level of muscular condition to maintain on court performance (also lower risk of injury). Considering the exercise training, the speed and explosive force are the key factors to evaluate sports ability, which is very important to sports performance. One of the basic principles of sports training is to attach importance to the specificity of sports, which requires the speed and specificity of training to be close to at the time of competition (Cleary Dolcetti et al., 2019; Cronin et al., 2001; Mcclenton et al., 2008).

5. SUMMARY AND PRACTICAL IMPLICATION

To briefly sum up, this study reviewed the development of badminton sport, footwork classification and definition, traditionally employed exercise training, and resistance training. In the last part, a wearable resistance (WR) training intervention was introduced and discussed as this approach has been successfully employed in the training of other sports, aiming to introduce this method into badminton footwork training on-court. Being a typical acyclic motion on badminton court, the training of badminton footwork shall consider integrating the WR approach with wearable and adjustable loads. This training intervention may attach incremental loads to either the whole body or regional limbs to practice real-competition movements with high-velocity, thus forming motor adaptation. The adaptation from task-specific training may increase footwork efficiency and transfer to match situation.

Future research and integration of wearable resistance should include comparisons of different lower body WR loading configurations from acute and longitudinal analysis, thus forming scientific evidence to support selection and design of training scheme for badminton footwork.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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