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Effectiveness of a low-frequency sports-specific resistance and plyometric training programme: the case of an elite junior Badminton player

Geoff Middleton, University of Lincoln*, *UK*
Daniel C. Bishop, University of Lincoln, *UK*
Chris Smith, University of Lincoln, *UK*
Thomas I. Gee, University of Lincoln, *UK*

Abstract

This intervention aimed to improve Badminton-specific functional performance of an elite under-19 player (18 years) via a single-weekly resistance and plyometric training (RPT) session for 8-weeks. The athlete's 'response-to' and 'withdrawal-from' the RPT were assessed. The athlete (stature: 1.77 m, mass: 81.5 kg) completed the RPT intervention throughout a competitive season. Performance testing was conducted at; baseline, post-intervention (8-weeks) and after withdrawal-from the RPT (16-weeks). Jump height and throwing distance were assessed via countermovement jump (CMJ), standing long-jump (SLJ) and one-arm (1-MBT) and two-arm (2-MBT) medicine-ball throws respectively. Speed and agility were assessed by 5 m and 10 m sprints and 'sideways' and 'four-corner' tests respectively. A positive change from baseline to post-intervention (8-weeks) was observed in: CMJ (+0.07 m), SLJ (+0.13 m), 1-MBT (+2.25 m) and 2-MBT (+0.26 m). Observed changes in speed and agility were minimal. At the 16-weeks, small declines in CMJ, SLJ, 1-MBT and 2-MBT (0.04 m, 0.04 m, 0.52 m and 0.05 respectively) existed. Small improvements in 5 and 10 m sprint times (-0.12 s to -0.09 s) and side-ways agility were observed (-0.11 s to -0.39 s), possibly explained by conditioning effects of training and competition. An 8-week Badminton-specific RPT programme provided favourable increases in jumps and MB throws. However, such positive changes were not sustained following the withdrawal period.

Keywords: badminton, resistance training, plyometrics, case study, power assessment, elite

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*Corresponding Author: Geoff Middleton, School of Sport and Exercise Science, University of Lincoln Brayford Pool Lincoln LN6 7TS United Kingdom. Phone: +44 (0) 1522 837308 E-mail: gmiddleton@lincoln.ac.uk

Introduction

Badminton is described as a multi-directional explosive sprint sport (Hughes & Cosgrove, 2007; Sturgess & Newton, 2008) requiring players to demonstrate intense rhythmic movements which include shuffling, jumping, twisting, stretching and striking combined with a superior reactive ability (Ooi et al., 2009). Research on elite match play illustrates the high intensity nature of the sport, with rallies typically lasting ~10 s (Hughes & Cosgrove 2007), with short rest periods between points (typically 27-30 s) and a men's singles games lasting on average 21 min (Abián et al., 2014). Furthermore, heart rates of elite competitors have been found to reach and maintain maximal levels (186-201 b•min-1) during match-play (Cabello Manrique & González-Badillo, 2003). Combined with the intense metabolic demands, players are required to demonstrate high levels of flexibility, speed, power and agility over competitors during rallies.

To mimic the high intensity demands of Badminton researchers have advocated training which involves actions performed with short (15-20 s) and very short (6-10 s) intervals (Cabello Manrique & González-Badillo, 2003). Training programmes should also emphasise the sport-specific movement patterns to generate greater performance related improvements (Duncan, 2006; Heang et al., 2012; Sturgess & Newton, 2008). In addition, combining resistance training and plyometric training has been shown to enhance high-intensity Badminton performance in measures of upper and lower body power, speed and agility (Heang et al., 2012; Sturgess & Newton, 2008).

To the author's knowledge, little has been published regarding the explicit demands and details of elite junior Badminton and the associated resistance and plyometric training (RPT) programmes used at this level. Elite junior Badminton players often have conflicting demands of full-time sport and education. Given these commitments, identifying low-frequency, yet successful training techniques can be beneficial for incorporation within current athlete training schedules. Although RPT programmes are considered and frequently used within racket sports (Reid & Schneiker, 2008; Sturgess & Newton, 2008), there is little evidence to substantiate the efficacy of this form of training within elite standard players. To address this issue, the current case study intends to illustrate the effects of a RPT using a single-subject design.

The aim of this case study was to improve Badminton-specific functional performance with an elite under-19 player by using a single weekly RPT session for 8-weeks. This was achieved by evaluating the athlete's 'response to' and 'withdrawal from' the RPT training. Observed at testing intervals across several time-points in a competitive Badminton season; an example of single-subject research, using the ABA design (Kinugasa et al., 2004). The primary purpose of conducting this study was to assist the development of an elite standard junior player who had not previously conducted any sports-specific RPT. The second outcome was to observe the effects of integrating a weekly 60 min sports-specific RPT session into their current schedule in the competitive season.

Methodology

The Athlete

The athlete (age: 18 years, stature: 1.77 m, mass: 81.5 kg) was a recognised 'junior' Badminton player that had represented their nation at under-19 level and was ranked within the top three nationally in men's doubles. For anonymity purposes the player will be referred to as 'the athlete' in this case study. After consultation with both athlete and their coach, the athlete was approached by the lead author to develop sport-specific training methods with the addition of a RPT to their current schedule. Specifically, the coach felt that the inclusion of specialised sport-specific RPT was a logical step in the development of the athletic attributes necessary for high level Badminton performance. The athlete's long-term aim was to become a full-time senior professional player. The athlete was a full-time student, attending Sixth-form college.

Research Approach and Ethics

The authors adopted a humanist philosophy and worked within a positivist paradigm which was central to the procedures that were conducted. The authors employed a mono-disciplinary support approach and utilised a range of literature to carefully guide the case study's approach (Baechle & Earle, 2008; Kinugasa et al., 2004), intervention development (Potach & Chu, 2008; Sturgess & Newton, 2008) and assessment scenarios (Hughes & Cosgrove, 2007; Ooi et al., 2009).

This case study had a scientific focus in testing the athlete's response to and 'withdrawal' from a RPT programme; an example of an applied single-subject research, using the ABA design (Kinugasa et al., 2004). Applied research designs are a rarity in the literature, however they do provide understanding to how well training methods (interventions) work in practice (Kinugasa et al., 2004). The athlete was classified as a research participant in this context, with the case study receiving ethical clearance from the School of Sport and Exercise Science Ethics Committee prior to commencement of the intervention. The case study followed the principles of the Declaration of Helsinki (World Medical Association, 2013). The athlete provided informed consent after carefully considering content and rationale, and was provided with the opportunity to ask questions.

Needs Analysis and Case Justification

The athlete presented no health concerns (after completing the relevant medical forms), reported feeling 'fit and healthy' and the athlete had not suffered any injuries in the last two years. The athlete was familiar with resistance training (two years' experience) and completed two weekly strength-based resistance training sessions (a basic circuit of fixed resistance machines and free weights) for 3 sets of 8-12 repetitions. After admitting that they had not attempted any sport-specific RPT training before, it was agreed by the athlete, coach and practitioners that the most sensible course of action was to introduce one weekly RPT session to the current microcycle of the athlete. This was to be administrated for 8-weeks to compliment the athletes microcycle during the competitive Badminton season. The athlete's typical microcycle at this point in the season is shown in Table 1. Training details and intensity domains were indicated by coach and athlete after discussions with the lead author.

Following guidance by Baechle and Earle (2008) the needs analysis had two main sections; an evaluation of the sport (by observation of performance and a literature review on the physiological demands of Badminton) and a physical assessment of the athlete (performance testing - at 'baseline') and are outlined in the following sections.

Table 1. The athlete's typical microcycle during the case study

Week day	Training details	Daily intensity
Monday	On-court training	Moderate-High
Tuesday	Weights session*	High
	On-court training	
Wednesday	Match-play training	Moderate
Thursday	*RPT session*	High
	On-court training	
Friday	On-court training	Moderate-High
Saturday	Weights session* / Tournament day	Moderate-High
Sunday	Rest day / Tournament	Low / High

Note. *Weight session sessions consisted of: bench press, bicep curl, tricep extension, frontal raise, lateral raise, back squats, lunges, forearm curl, bent over row and abdominal curl. Training details and intensity domains were indicated by athlete and coach

Intervention plan

The RPT intervention was completed once-a-week, on the same day, by the athlete during the 2011/12 competitive Badminton season between January and May. The overall training schedule remained consistent to the microcycle during this period. The intervention was designed to provide a balance between upper-and lower body exercises (Table 2). The athlete completed two practical and instructional sessions before embarking on the programme. Each session was supervised by accredited practitioners (US National Strength and Conditioning Association and the UK Strength and Conditioning Association) throughout the 8-week intervention and took place in a temperature controlled room (19-21 °c). The athlete completed a brief warm-up (5-10 min) comprising movements advocated by Potach and Chu (2008). The main exercise components in the programme were designed from recommendations for senior elite Badminton players (Sturgess & Newton, 2008) and modifications of exercises advocated for improving power (Foran, 2001;

Potach & Chu, 2008). Any modifications were specific to the movements associated with Badminton after consultation with both coach and athlete. The programme followed standard recommendations, using low to moderate intensity exercises for beginner athletes participating in plyometric activity with 80-100 foot contacts per session (Potach & Chu, 2008).

As the athlete was unfamiliar with RPT the programme was designed to emphasise explosive movements and elicit responses within the speed-strength component of the force velocity curve. The programme was therefore developed by increasing the quality, speed and range of movement only. The weighted items used over the course of the 8-week period remained the same. There was no direct cost attached to this intervention with only practitioner time and existing University S&C resources used.

Table 2. Resistance and Plyometric Training programme

Component	**Initial sets × repetitions**
Warm-up exercise/drills:	
1. Jogging	
2. Backward jogging	
3. Forward lunging	
4. Skipping (swing arms)	
5. Crawling	
6. Alternate low-intensity bounding	all 2 × 15 m
Main exercises:	
1. Multi-direction lunges (12kg kettlebell x2)*†	4 × 8
2. Plyometric push-up (30cm height)	3 × 5-6
3. Lunge return hops*	3 × 5-6
4. One-handed medicine ball slams (4kg ball)*†	3 × 5-6
5. Drop back and jumps*	3 × 5-6
6. Medicine ball throws from shoulder (2kg ball)*†	3 × 5-6
7. Standing jump with lateral acceleration	10 × 5m
8. Alternate bounding with 1-arm action	3 × 15m

Note. *Exercises 3-6 incorporated both left and right sides of the body. †Resistance exercises Rest periods were set at 2 min between each set. Designed from recommendations by Sturgess & Newton, (2008), Potach & Chu, (2008) and Foran (2001)

Performance Assessment

Data were collected at three different time-points: at baseline (pre-intervention); post-intervention (at 8-weeks); and after withdrawal from the RPT (at 16-weeks). The athlete's anthropometric data were collected: height to the nearest 0.01 m (Seca, Hamburg, Germany); body mass to the nearest 0.1 kg (Seca, Hamburg, Germany); skinfold thickness to the nearest 0.1 mm (Harpenden Calipers, Burgess Hill, Baty International, England). Seven skinfold sites were assessed on the right side of the body according to standards set for measuring athletes (Norton et al., 2000). The chosen anthropometrist had a typical error of measurement of 1.62% and conducted skinfold assessment at each testing interval.

Performance tests were selected based on previous published research within elite Badminton players (Hughes & Cosgrove, 2007; Ooi et al., 2009) and recommendations for other practical types of assessment for the upper-body (Foran, 2001). Furthermore, the tests theoretically linked to the dominant physiological performance attributes which the authors felt were valuable for Badminton performance; speed, agility, power after consulting the literature and the athlete's coach.

The athlete completed a habituation session one-week before the commencement of the baseline testing session. Jump height (m) were assessed by a countermovement jump (CMJ), using a contact jump mat (SMARTJUMP, Fusion Sport, Brisbane, Australia). Jump distance (m) was assessed by a standing long-jump (SLJ). Both jumps followed protocols described by Hughes and Cosgrove (2007). Upper body tests assessed arm power with both one- (1-MBT) and two-arm (2-MBT) (dominant hand) medicine-ball (2 kg) throws, using modified protocols by Foran (2001). Speed was assessed by a 10 m sprint (Foran, 2001) with a 5 m split using electronic timing gates (SMARTSPEED, Fusion Sport, Brisbane, Australia). Agility was assessed by the Badminton-specific assessments outlined by Ooi et al. (2009); the 'sideways' and 'four-corner' tests (s).

As a matter of monitoring the effects of RPT on the athlete, the client was asked to complete a self-reported 'wellness' diary, in the form of a small paper based form, for two days (6 days in total) after each training session (Brewer, 2008). This was administered in weeks 2, 4 and 6 during the intervention. The diary requires self-rating of workload (heavy/moderate/light), sleep, daily nutrition and attitude/energy for training (excellent/good/average/poor). Resting heart rate (bpm), body mass (kg) and number of hours were also reported by the athlete.

Data Analysis

To distinguish real changes from the forthcoming RPT, standard error of measurement (SEM) on each test was calculated at the initial baseline testing session with the athlete and same administrator (intra-SEM). To calculate error, the athlete was re-tested after a 5-min rest period after each initial baseline assessment. Highlighting acceptable human typical error margins is critical when determining intervention effects (such as athlete improvement or decline) because practitioners are required to distinguish or verify effects of training or whether changes are merely the result of the inherent variation in testing methods (Goto & Mascie-Taylor, 2007). The typical error of measurement assumed: for the CMJ: 0.01 m; for the SLJ: 0.03 m; and for the 1-MBT and 2-MBT: 0.06 m and 0.06 m, respectively. The typical error of measurement calculated: for the 10 m sprint, with a 5 m split: 0.01 s and 0.01 s; and for the sideways and four-corner tests: 0.23 s and 1.04 s, respectively. In addition the 'smallest practical effect' (SPE) of change for an assessment allows for interpretation of performance changes over time; to assess whether observed changes in performance are 'practically' meaningful and/or true. SPE is calculated from the product of 0.3 [which represents the smallest standardised change in mean for a group of trained participants; Hopkins et al. (2009)] multiplied by the between-participant standard deviation across either a baseline trial or repeated reproducibility oriented trials. For the assessments of CMJ, 2-MBT, 5 m and 10 m sprint data collected from previous cohorts of court-based athletes was used to interpret observed changes following the intervention based on SPE (Gonzalo-Skok et al., 2015; Mayhew et al., 1995).

Results

Results from the testing battery over the course of the competitive season are presented in Table 3. After the 8-week RPT programme the assessments requiring instantaneous maximal power showed improvement. The height of the CMJ improved 0.07 m (+14% from baseline). SLJ distance increased by 0.13 m (+5% from baseline). Both 1-MBT and 2-MBT improved by 2.25 m (+ 22% from baseline) and 0.26 m (+3% from baseline) respectively.

After the withdrawal period (at 16-weeks), there was a decline in performance in all the explosive power tests. CMJ height reduced by -0.04 m (-8% at 8-weeks). SLJ distance decreased by -0.04 m (-1.6% at 8-weeks). Both 1-MBT and 2-MBT also declined: -0.52 m (-4.2% at 8-weeks) and -0.05 m (-0.5% at 8-weeks), respectively.

The 10 m sprint time and the two agility tests in contrast provided data which suggests that small improvements were made past completion of the RPT. At 16-weeks (8-weeks post intervention) the athlete's quickest times were recorded: 10 m sprint, with 5 m split: 1.92 s (-4.5% at 8-weeks) and 1.13 s (-9.6% at 8-weeks); side-ways agility: 15.13 s (-2.5% at 8- weeks); four-corner agility: 29.00 s (-0.2% at 8-weeks). Compared to baseline, at 16-weeks the athlete recorded improvements with CMJ (+ 0.03 m), SLJ (+0.09 m), 1-MBT (1.73 m), 2-MBT (0.21 m), 10m sprint (-0.03 s) with 5 m split (0.03 s), side-ways agility test (0.37 s) and the four corner agility tests (0.28 s).

Table 3. Physiological assessments pre-and post-intervention

Test battery	Baseline assessment	Post intervention (8-weeks)	Final assessment (16-weeks)	Errors of measurement (calculated at baseline)
Height (m)	1.77	1.77	1.77	-
Weight (kg)	81.5	82.7	82	-
? 7 skinfolds (mm):	55.2	54.6	57.3	-
CMJ height (m):	0.43	0.50	0.46	0.01
SLJ (m)	2.41	2.54	2.50	0.03
1-MBT (m)	10.10	12.35	11.83	0.06
2-MBT (m)	9.20	9.46	9.41	0.06
10m sprint (s):	1.95	2.01	1.92	0.01
with 5m split (s):	1.16	1.25	1.13	0.01
Sideways AT (s):	15.50	15.52	15.13	0.23
Four-corner AT(s):	29.28	29.06	29.00	1.04

Note. *The athlete was given two measured attempts at each test; best result shown.
Key: CMJ = Countermovement jump; SLJ = Standing long jump; 1-MBT = One arm-medicine ball (2kg) throw 2-MBT = Two arm-medicine ball (2kg) throw; Sideways AT = Sideways Badminton agility test; Four-corner AT = Four-corner Badminton agility test.

Discussion

Interpretation of Baseline Assessment

Information from the baseline assessment indicated that both the athlete's CMJ (0.43 m) and SLJ (2.41 m) jumps were below elite level male standards; 0.46 m (average data from: Ooi et al., 2009) and 2.47 m (average data from: Hughes and Cosgrove, 2007) respectively. The athlete's initial assessment on both the 'sideways' (15.5 s) and 'four-corner' (29.3 s) tests very comparable and even superior than elite level male standards; 15.3 s and 32.4 s (average data from: Ooi et al., 2009) respectively. Given the baseline results and the contrast to elite standards, the athletes jump capability was seen as a weakness and certainly an aspect to improve upon. An expected outcome from completing the RPT programme was the improvement in jump capability.

Interpretation of Post Intervention and Post Withdrawal Assessments

From data collected previously, the smallest practical effect was calculated for CMJ (0.01 m), 2-MBT (0.24 m) 5 m sprint (0.03 s) and 10 m sprint (0.03 s) tests amongst groups of junior male basketball players (Gonzalo-Skok et al., 2015; Mayhew et al., 1995). With this cohort being a comparable athlete type to the featured athlete in this case study; young, male, repeated sprint/effort court-based games players, meaningfulness of performance changes within the aforementioned assessments in the current case can be interpreted to some extent. The athlete's performance increases within the CMJ and 2-MBT exceed the previously established SPE for these assessments (Gonzalo-Skok et al., 2015; Mayhew et al., 1995). Therefore the authorship team are confident that a practically meaningful performance increase occurred within these measures following the RPT intervention. However, 5 m and 10 m sprint performance was shown to decrease at 8-weeks beyond the level of the previously established SPE, indicating a meaningful loss in speed. This may have been partly due to the addition of overall body mass between the baseline and 8-week assessment (+1.2kg). The 5 m and 10 m sprint performance then seemingly exceeded baseline values by 0.03 (the magnitude of previously established SPE) at the 16-week assessment. At the 16-week assessment both CMJ and 2-MBT performance were decreased in relation to the 8-weeks assessment. However, values exceeded those established at baseline when considering SPE, which is indicative of a residual training effect in relation to upper and lower body power.

The athlete did not provide any negative feedback during the course of the intervention and found developing the new training elements purposeful and enjoyable. The athlete attended all sessions and adhered to the programme as intended. Slight muscular soreness in the initial two weeks was verbally reported, but both athlete and coach felt that this did not influence other aspects of training in the season. No unusual recordings were made with the wellness diary: resting heart rate (52 ± 1.8 b•min-1), body mass (81.8 ± 0.4 kg) and number of hours sleep (8.3 ± 0.8 hours) illustrated little variation. Categorical variables were rated as follows: workload (heavy x3/moderate x1/light x2), sleep (good x5/average x1), daily nutrition (good x2/average x3/ poor x1) and attitude/energy for training (excellent x2/good x4). The coach, athlete and lead author where happy that the workload (x3 heavy) was a result of successful tournament participation where the athlete had reached the latter stages of the competition. There was little to suggest that the addition of the RPT had a negative consequence on Badminton performance (match-play did not regress). Indeed, the coach and athlete felt that standards had either maintained or improved during the intervention and other training elements in the microcycle had not been compromised.

The authorship team attempted to avoid any confirmation bias during the work by having two assessors present on each assessment day. Furthermore, the athlete was not reminded about any previous scores prior to the testing elements as a motivation. A limitation of the work was the element of progression the athlete received during the intervention. With the quality, range and speed of movement concentrated on, after the 8-week period it is possible a 'ceiling effect' may have been reached with the adaption to this type of training from the exercises used. Whilst exercises were not added or weight increased in certain exercises the athlete progressed within the sessions by completing to the athlete's maximum explosive ability.

Conclusion

The athlete's response to and 'withdrawal' from the RPT training was observed at testing intervals across several time-points in a competitive Badminton season; an example of single-subject research, using the 'ABA design' (Kinugasa et al., 2004). The addition of a low-frequency Badminton-specific RPT assisted in power development in several tests which demand explosive power such as throwing and jumping type activities. The authors assume the substantial improvement in CMJ height at 8-weeks (0.07 m) to a combination of neuromuscular and strength/power adaptations as a result of the RPT training. Given the relative novelty of the programme's repetitive jumping movements to the athlete, it would be reasonable to attribute that a level of skill acquisition on this movement (and potentially others) is a contributing factor.

Interestingly, slight improvements were observed after the withdrawal of the RPT with the sprint and agility tests conducted (at 16-weeks). Although somewhat unexpected, it may be theorised that these improvements following the withdrawal period were due to specific conditioning effects the athlete received as a result of training and competition during the competitive season.

This case study used an ABA (reversal) applied single-subject design to analyse the effects of a brief S&C intervention on an elite Badminton player (Kinugasa et al., 2004). In light of the findings from this case, practitioners attempting to replicate and integrate similar low frequency RPT programmes may expect to see increases in athletic power after administration, without negatively affecting other aspects of sport-specific performance.

References

Abián, P., Castanedo, A., Feng, X. Q., Sampedro, J., & Abian-Vicen, J. (2014). Notational comparison of men's singles badminton matches between Olympic Games in Beijing and London. *International Journal of Performance Analysis in Sport, 14,* 42-53.

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength and conditioning.* (3rd ed.) Champaign, Il: Human Kinetics.

Brewer, C. (2008). *Strength and conditioning for sport: A practical guide for coaches.* Leeds: Coachwise Ltd.

Cabello Manrique, D., & González-Badillo, J. J. (2003). Analysis of the characteristics of competitive badminton. *British Journal of Sports Medicine, 37,* 62–66.

Duncan, M. J. (2006). Plyometric training in Gaelic Games: A case study on a county-level hurler. *International Journal of Sports Physiology and Performance, 1,* 361-364.

Foran, B. (2001). *High-Performance Sports Conditioning.* Champaign, Il: Human Kinetics.

Goto, R., & Mascie-Taylor, C. N. (2007). Precision of measurement as a component of human variation. *Journal of Physiological Anthropology, 26,* 253-256.

Gonzalo-Skok O, Serna J, Rhea MR, Marín PJ. (2015). Relationships between functional movement tests and performance tests in young elite male basketball players. *International Journal of Sports Physical Therapy. 10,* 628-38.

Hopkins, W. G., Marshall, S. W., Batterham A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41,* 3-13.

Heang, L. J., Hoek, W. E., Quin, C. K., & Yin, L. H. (2012). Effect of plyometric training on the agility of students enrolled in required college badminton programme. *International Journal of Applied*

Sports Sciences, 24, 1-18.

Hughes, M. G., & Cosgrove, M. (2007). Badminton. In: Winter, E. M., Jones, A. M., Davison, R. C., Bromley, P.D., & Mercer, T.M. (Eds.), *Sport and exercise physiology testing guidelines: The British Association of Sport and Exercise Science guide* (pp. 214-219). London: Routledge.

Kinugasa, T., Cerin, E., & Hooper, S. (2004). Single-subject research designs and data analyses for assessing elite athletes' conditioning. *Sports Medicine, 34,* 1035-1050.

Mayhew, J.L., Bemben, M.G., Rohrs, D.M., Piper, F.C. & Willman, M.K. (1995). Comparison of upper body power in adolescent wrestlers and basketball players. *Pediatric Exercise Science, 7,* 422-422.

Norton, K., Marfell-Jones, M., Whittingham, N., Kerr, D., Carter, L., Saddington, K., & Gore, C. (2000). Anthropometric assessment protocols. In: Gore, C. J. (Ed.), *Physiological tests for elite athletes* (pp. 66-85). Champaign, Il: Human Kinetics.

Ooi, C. H, Tan, A., Ahmad, A., Kwong, K. W., Sompong, R., Mohd Ghazali, K. A., & Thompson, M. W. (2009). Physiological characteristics of elite and sub-elite badminton players, *Journal of Sports Sciences, 27,* 1591-1599.

Reid, M., & Schneiker, K. (2008). Strength and conditioning in tennis: current research and practice. *Journal of Science and Medicine in Sport, 11,* 248-256.

Potach, D. H., & Chu, D. A. (2008). Plyometric training. In: Baechle, T. R, & Earle, R. W. (Eds.), *Essentials of strength and conditioning* (pp. 413-456). Champaign, Il: Human Kinetics.

Sturgess, S., & Newton, R. U. (2008). Design and implementation of a specific strength program for badminton. *Strength Conditioning Journal, 30,* 33-41.

World Medical Association. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *Journal of the American Medical Association,* 310, 2191