2025, Retos, 62, 894-900

The effects of step aerobic training on balance in female badminton players

Los efectos del entrenamiento aeróbico con step sobre el equilibrio en jugadoras de bádminton

*Ashira Hiruntrakul, *Chittraporn Thongkong, *Charee Jansupom, ** Nur Azis Rohmansyah, *Neranoch Bumrung
*Khon Kaen University (Thailand), **Univeritas negeri Yogyakarta (Indonesia)

Abstract. Step-aerobic training (SAT) has been effective exercise pattern on balance. Very few studies focused on female badminton players. Objective: was to compare the effects of SAT on balance in female badminton players. Methods: twenty female participants were divided into the experimental group (EG), practiced a step aerobics tempo using a speed controller at a speed range of 125-140 beats per minute (bpm) and height of 4, 6, and 8 inches practice for 30 minutes 3 days a week, together with the 8 week badminton training program (n=10, age: 16.70±1.15 years; body weight = 54.19±2.86 kg; body height = 164.10±3.66 cm; fat = 23.32±2.07 percent; muscle mass = 41.47±2.24 kg). The control group (CG) performs the badminton program training. (n = 10, age: 16.60±1.17 years; body weight = 53.98±3.09 kg; body height = 164.20±3.32 cm; fat = 23.52±2.36 percent; muscle mass = 41.23±1.55 kg). Results: The balance test from eye open, eye close firm and foam surface sway index (°/sec) after 4 weeks (eye open firm; p=0.024, eye close firm; p=0.028) and 8 weeks (eye open firm; p=0.001, eye close firm; p=0.001, eye open foam; p=0.046, eye close foam; p=0.028) in the EG was significantly better than before (p<0.05), but no difference in the CG. Conclusion: the SAT at 6 - 8 inches in height using 125 - 140 bpm has a beneficial effect on balance, which allows athletes to be more efficient in moving quickly in a short training period without losing balance.
Keywords: badminton, step-aerobic training, balance, sway index, music rhythm

Resumen. El entrenamiento aeróbico con pasos (SAT) ha sido un patrón de ejercicio efectivo para el equilibrio. Muy pocos estudios se centraron en jugadoras de bádminton. Objetivo: comparar los efectos del SAT sobre el equilibrio en jugadoras de bádminton. Métodos: veinte participantes femeninas se dividieron en el grupo experimental (GE), practicaron un tempo de aeróbicos con pasos usando un controlador de velocidad a un rango de velocidad de 125-140 pulsaciones por minuto (ppm) y una altura de 4, 6 y 8 pulgadas. práctica durante 30 minutos 3 días a la semana, junto con el programa de entrenamiento de bádminton de 8 semanas (n = 10, edad: 16,70 ± 1,15 años; peso corporal = 54,19 ± 2,86 kg; altura corporal = 164,10 ± 3,66 cm; grasa = 23,32 ± 2,07 por ciento; masa muscular = 41,47 ± 2,24 kg). El grupo control (GC) realiza el entrenamiento del programa de bádminton. (n = 10, edad: 16,60 ± 1,17 años; peso corporal = 53,98 ± 3,09 kg; altura corporal = 164,20 ± 3,32 cm; grasa = 23,52 ± 2,36 por ciento; masa muscular = 41,23 ± 1,55 kg). Resultados: El equilibrio después de 4 y 8 semanas en el GE fue significativamente mejor que antes (p ≤ 0,05), pero no hubo diferencia en el GC (p > 0,05). Conclusión: el SAT a 6 - 8 pulgadas de altura utilizando 125 - 140 ppm tiene un efecto beneficioso sobre el equilibrio, lo que permite a los atletas ser más eficientes al moverse rápidamente en un corto período de entrenamiento sin perder el equilibrio.
Palabras clave: bádminton, entrenamiento aeróbico con step, equilibrio, índice de balanceo, ritmo musical.

Fecha recepción: 30-07-24. Fecha de aceptación: 01-10-24
Neranoch Bumrung
Neranochh@kkumail.com

Introduction

Badminton is one of the most popular racquet sports all around the world (Hamed, 2017). The nature of this sport is the movement in different directions of the field, both sides of the playing field take turns hitting the ball quickly for the opponent to receive or hit the ball in error, the shuttlecock hit by both athletes rackets had an average speed of 417 kph (Guinness World Reords, 2017). Athletes will need a specific skill to jump smashes, lunges, and changes of direction to different positions of the field to receive or hit the ball with speed to gain an advantage against the opponent in scoring (Sturgess & Newton, 2008; Laffaye et al., 2015; Lee & Loh, 2019). In addition, badminton players must react to the shuttlecock in motion and adjust body position quickly and continuously throughout the game, and they must maintain their center of gravity within the base of support while performing rapid and unbalanced upper limb movement (Faude et al., 2017; Chang et al., 2013). Balance ability is related to multiple factors, including visual information; such as more swings in the center of gravity (CoG) observed when standing with closed eyes than with them open (Lord et al., 1991). There are also reports suggesting that the CoG fluctuates less as the strength of the lower leg muscles increases (Lin & Woollacott, 2005). In postural stability, an appropriate level of contraction of the lower extremities is required based on sensory information obtained from the plantar surface (Lord et al., 1991). In brief, balance is an ability influenced by various factors, and balance improvement is a crucial advancement skill (Chang et al., 2013), with a low ability to balance, the stability is body imbalanced, thus increasing the burden on the lower limbs. The balance system must have compensated and improved as the fast CoG can repeatedly shift the CoG outside the support area (base of support) and challenge the body bal-

2025, Retos, 62, 894-900

ance. In badminton, the physical load has been reported as being marked (Faude et al., 2017), and there is a high risk of injury (Yung et al., 2007).

Therefore, it is important to reduce the risk of injury and increase the performance by enhancing balance ability and badminton also require good balance performance and speed to move quickly in six directions of the court without losing balance (Phomsoupha & Laffaye, 2014). For badminton players, balance also plays an important in addressing issues of the controlled CG and other situations challenging their balance, such as into the movement, hitting the shuttlecock in a twisting and rotation movement to perform offensive and defensive actions. It makes sense to practice balance exercises to improve badminton movement efficiency.

Many training methods can help develop good balance, such as weight lifting, yoga, and jumping rope, and the most popular training is step aerobic training. Previous studies have found that step aerobic training that uses a movement speed of 100-110 and 120-150 times per minute and a height of 4-8 inches can stimulate the muscles that contribute to better balance (Sedigheh et al.,2016; Nithiya et al., 2017). Because SAT is a good measure of badminton players' movement performance (Hughes & Bopf, 2005). Step aerobics is a form of exercise that is very popular in gyms or health centers. It was a development from aerobic dance, step aerobics training uses the same music rhythm as the aerobic dance but uses the step-box to step up and down instead of dancing, jumping on the ground or running gives the muscles more work and the height can adjust to increase the intensity of training (Nithiya & Saroja, 2017). Recent studies have shown that step aerobics training is an activity that has a low impact on the knees and ankles and therefore is safe to practice (Santos et al., 2002). Therefore, this study aimed to the effects of SAT on balance in female badminton players. The researchers hope that this study can provide useful information on how to optimize athletes and provide a variety of options for coaches and trainers to use in training programs designed for athletes effectively.

Materials and Methods

Participants

Twenty female participants were badminton players who had undergone physical activity readiness questionnaire (PAR-Q) assessment to show that they were healthy. The subjects performed the test by peak muscle power as a main criterion and, using the results of muscle power to rank the ability from highest to lowest. Muscle power test with Humac NORM isokinetic dynamometer, knee extensors, and knee flexors was tested with a resistance of 180°/sec. 15reps with each leg of the leg kick test with full force on both the forward leg extended and the inward flexion. Based on reports of instrumental confidence by Habets et al., (2018). Reliability of the Humac NORM isokinetic dynamometer used to test knee muscles has an Intraclass Correlation Coefficient (ICC) of 0.74 - 0.89, which is of good reliability. All participants were divided into two groups [EG (n=10) and CG (n=10)], and before to participating in the research, subjects were provided with detailed instructions and informed written consent. This study was approved in advance by the Ethics Committees of Khon Kaen University (Khon Kaen, Thailand). Each participant voluntarily provided written informed consent before participating.

Procedure

The EG performed SAT three days per week for training period was 8 weeks and the CG practiced the badminton program training. The SAT program is designed according to the guidelines of the American College of Sports Medicine (ACSM, 2016). Which will receive SAT in 7 movement patterns, consisting of the side tap, knee up, over the top, turn step, cross back, across the top chasse, and indecision. All movement pattern of SAT, it is controlled by a music rhythm with a speed between 125 and 140 beats per minute and steps aerobic height 4, 6 and 8 inches (Nithiya & Saroja, 2017). SAT performed 30 minutes, 3 sessions per week: warm-up for 5 minutes, step aerobic workout for 20 minutes, and a cool down and stretching lasting 5 minutes. For weeks 1-2, training each for 20 seconds, rest 20 seconds for each moves, and total of 3 sets, using a 4-inch step aerobic height and a speed of 125 bpm. Weeks 3-4 use a 6-inch step aerobic height, a speed of 130 beats per minute, and weeks 5-8, training each for 30 seconds, rest 30 seconds between moves, for a total of 2 sets, use height step aerobic 8 inch and control the speed at 140 bpm.

Balance test

We tested balance ability by Biodex Balance System (950-440 BALANCE SYSTEM™ SD, USA). Based on reports of the confidence level of the instrument by Nicole et al., 2018, there was an Intraclass Correlation Coefficient (ICC) at 0.75 - 0.92, which is of the good-excellent level of reliability. This study used a balance test by Biodex Balance System with Modified Clinical Test for Sensory Interaction and Balance (m-CTSIB) including eyes open firm surface, eyes close firm surface, eyes open foam surface, eyes open foam surface.

Statistical analysis

All data are presented as means ± standard deviations. After normal distribution was examined by Shapiro-Wilk

2025, Retos, 62, 894-900

test, and when testing for normal distribution, two-way repeated measures ANOVA (group x time) was performed on the balance test using within-group, before, after 4 weeks, and 8 weeks factors and between-groups to compare the differences in balance performance before, after 4 weeks, and 8 weeks. Statistical analysis was performed using SPSS IBM 22. The statistical significance of $p < 0.05$.

Results

Table 1 shows that the mean ± standard deviation of baseline physiological variables between the EG were those who received SAT in combination with regular badminton program training, age was 16.70 ± 1.15 years, height was 164.10 ± 3.66 cm, body weight was 54.19±2.86 kg, BMI was 20.13±0.84, fat% was 23.32±2.07 and muscle mass was 41.47±2.24 kg. The CG was the regular badminton program training. Before the experiment, age was 16.60±1.17 years, height was 164.20±3.32 cm, body weight was 53.98±3.09 kg, BMI was 20.16±1.01 kg/m^2, fat% was 23.52±2.36, and muscle mass was 41.23±1.55 kg. Before the experiment, they were not different.

Table 1.
Physiological baseline variables

Variable	Experimental group (n=10)	Control group (n=10)	p-value
Age (years)	16.70 ± 1.15	16.60 ± 1.17	0.850
Height (cm)	164.10 ± 3.66	164.20 ± 3.32	0.950
Weight (kg)	54.19 ± 2.86	53.98 ± 3.09	0.877
Body mass index (kg/m^2)	20.13 ± 0.84	20.16 ± 1.01	0.938
Fat (%)	23.32 ± 2.07	23.52 ± 2.36	0.843
Muscle mass (kg)	41.47 ± 2.24	41.23 ± 1.55	0.786

The optimal standard of BMI for Asians is 18.5 – 22.9 (WHO, 2004)
The fat percentage standard for female athletes is 14 – 20 (ACE)

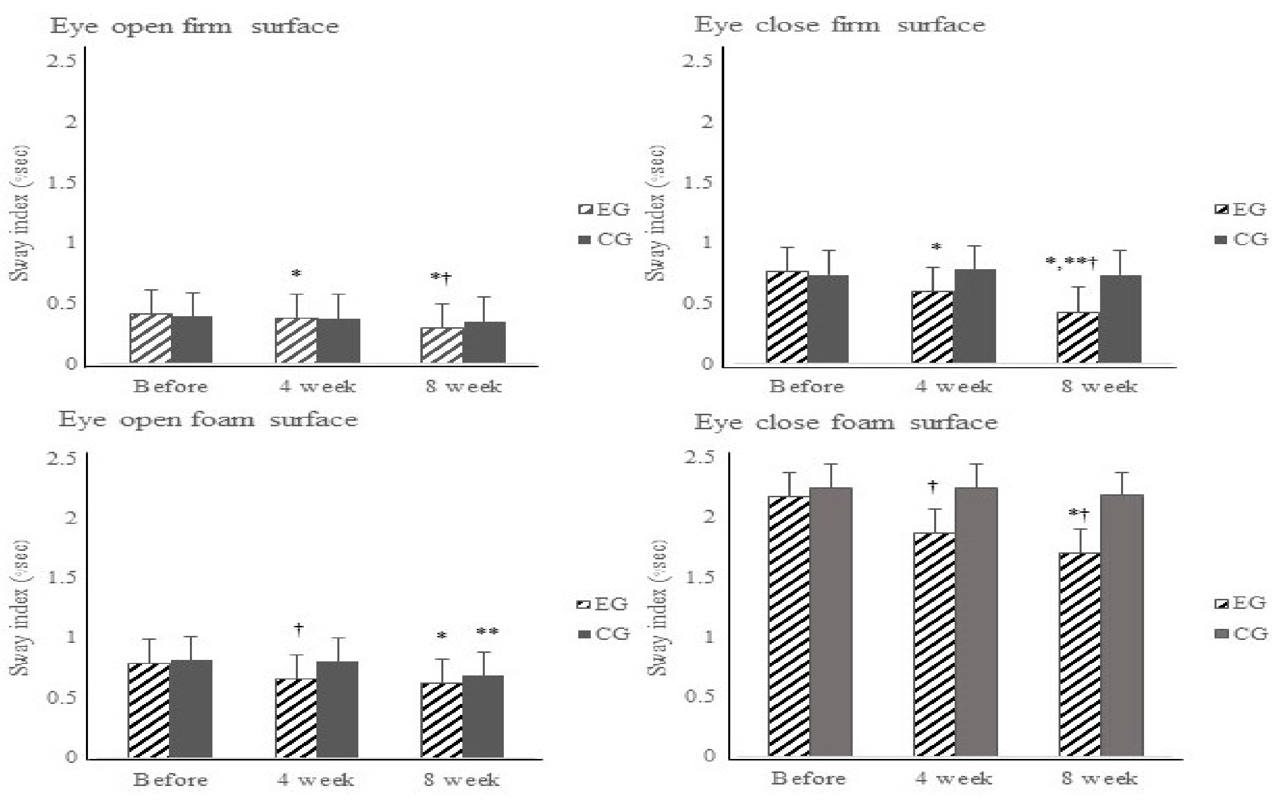

Figure 1. Balance ability in the experimental (EG) and control (CG). Values are mean SD. * $p < 0.05$, significantly different from before, ** $p < 0.05$, significantly different from week 4, † $p < 0.05$, significantly different between groups. The m-CTSIB Normative Sway index ranges are eyes open firm surface: 0.21-0.48, eyes closed firm surface: 0.48-0.99, eyes open foam surface: 0.38-0.71, eyes closed foam surface: 1.07-2.22, according to the Biodex Balance System Manual.

Eye open firm surface sway index (°/sec), within the group, it was found that the EG had after 4 weeks (0.38±0.07; p=0.024)and after 8 weeks (0.29±0.06; p=0.001) were significantly better than before (0.41±0.06). The CG, it was found that mean the eye open firm surface sway index (°/sec) before (0.39±0.03), after 4 weeks (0.37±0.02; p=0.562), and after 8 weeks (0.35±0.14; p=0.201) no difference. Compare between groups, it was found that the EG and the CG before and after the 4 weeks were not different. However, after 8 weeks, it was found that the EG had a statistically significant improvement in the eye open firm surface sway index (°/sec) than the CG (p=0.039).

Eye close firm surface sway index (°/sec) within group, it was found that the EG had after 4 weeks (0.60±0.15; $p=0.028$) and after 8 weeks (0.43±0.11; $p=0.001$) better than before (0.76±0.11) and after 8 weeks (0.43±0.11; $p=0.001$) improved than after 4 weeks (0.60±0.15). In the CG, it was found that the eyes close firm surface sway index (°/sec) before (0.74±0.21), after 4 weeks (0.78±0.37; $p=0.841$) and 8 weeks (0.74±0.14; $p=0.991$) were not different. Comparing between groups, we found no difference. But after 8 weeks, it was found that the EG had a statistically significant improvement in the eye close firm surface sway index (°/sec) compared to the CG ($p=0.001$).

Eyes open foam surface sway index (°/sec) within the group. It was found that the EG had an eyes open foam surface sway index (°/sec) after 8 weeks (0.62±0.13; $p=0.046$) was significantly better than before (0.79±0.27) at the 0.05 level. In the CG, it was found that the eyes open foam surface sway index (°/sec) before (0.81±0.28) and after 4 weeks (0.80±0.26; $p=0.982$), there was no difference. But after 8 weeks (0.68±0.14; $p=0.049$), it was found that it was significantly better than after 4 weeks (0.80±0.26) at the 0.05 level. After 4 weeks and 8 weeks, the eyes open foam surface sway index (°/sec) was not significantly different, but it was found that the EG had a better tendency to eyes open foam surface sway index (°/sec) than the CG.

Eyes close foam surface sway index (°/sec) within group found that the EG had the eyes close foam surface sway index (°/sec) before (2.11±0.14) and there was no difference after 4 weeks (1.87±0.39; $p=0.071$). But after 8 weeks (1.63±0.60; $p=0.028$), it was found that it was better than before. In the CG, it was found that before (2.25±0.30), after 4 weeks (2.24±0.15; $p=0.982$) and 8 weeks (2.18±0.23; $p=0.198$), it was not different. Compared between groups, they found that before there was no difference. However, after 4 weeks ($p<0.011$) and 8 weeks ($p=0.014$), it was found that the EG had an eyes close foam surface sway index (°/sec) was better than the CG ($p<0.05$).

Discussion

The objectives of this research study was to study the effects of SAT on balance in female badminton players before, after 4 weeks, and after 8 weeks. The stability test used in this study, the researchers tested the Sway index (°/sec) with the m-CTSIB. The study's goal was to look into the effects of SAT on balance in female badminton players. Best wishes to the best of our knowledge, this is the first research that will give important information on how to enhance athlete performance and provide a wide variety of alternatives for coaches and trainers to employ in training program design for athletes to continue effectively. The current findings may assist enhance badminton specific strength and conditioning routines and improve on-court performance.

The study's findings suggest that 8 weeks of step aerobic exercise improves adaptations in balancing performance. Because a well-developed balance ability necessitates not only strong lower limb strength to move swiftly, but also a good balance to manage body posture and overcome inertia induced by decelerations and brakings, adding extra balance training played a key part in enhancing such performance (Sekulic et al., 2013). A previous study found a strong association ($r = 0.83$) between balance and badminton performance during competitive matches (Tiwari & Srinet, 2011), which are remarkable by high-intensity rallies with brief rest intervals (ACSM, 2016). Although the direction and trajectory of the shuttlecock is determined throughout the competition. As a result, players are required to perform quick balance, multiple accelerations, decelerations, jumps, and lunge steps to hit the shuttlecock (Cabello, 2003), and good balance is essential for using the most effective footwork to get into the appropriate position and hit the shuttle on time. The results showed that the Sway index (°/sec) with the m-CTSIB test would be a performance indicator of badminton players on-court balance, as previously revealed that the most frequent moving patterns during the competition were forward, backward, and lateral movements (Phomsoupha & Laffaye, 2014). Meanwhile, while previous research has demonstrated positive adaptations in athletes' balance ability following SAT (Manouras, 2016; Asadi, 2017), the current study provides new findings indicating that combined training can increase improvement, which is consistent with the findings of Bouteraa et al., 2020, when similar training methods were applied to female basketball players. These findings indicated that badminton-specific balance abilities improved after step aerobic training but not as much as after combined training, which is consistent with previous research findings of significant adaptations in typical female and adolescent basketball players after combined training (Chaouachi et al., 2014; Bouteraa et al., 2020).

One possible explanation is that balance training improves players' body control, resulting in less time spent on the landing during jumps. In addition, it is feasible that balance training will help with lower-limb power improvement (Kean et al., 2006), discovered a 10% gain in vertical leaping after a 5-week balance training program that reduced CoG sway, helps athletes land more consistently with optimized vertical jump angles. Strength of lower body reaction, and posture control are key elements that influence an athlete's quick balance, body stability, and successful injury avoidance (Borghuis et al., 2008). In this aspect, the SAT paradigm may be beneficial for complex, high-speed, repeated dynamic badminton actions requiring a high level of body control. The coordinated work of the visual system, vestibular system, and proprioceptive system should be addressed to comprehend the advantage of SAT to badminton action from a physiological base. When a player changes directions quickly and the body becomes imbalanced, the aforementioned systems will work together to recover balance and maintain the body. During this process, proprioceptors and other co-sensors detect changes in body position, and the vestibular system sends signals to the central nervous system to develop motor perception. Therefore, to manage the body's balance, the central nervous system must send signals to the muscles, which in turn respond appropriately by adjusting the body's balance. As a result, the ability to change direction and accelerate, and decelerate quickly is specific to the combined effort of proprioceptors and effectors. SAT can only improve muscle (effector) function, not the cognitive system, which will improve by practicing balance. For this reason, we should focus on SAT to improve the efficiency of both the cognitive system and muscle function at the same time. Our study results demonstrated the positive benefits of the step aerobic training paradigm on badminton balance skills, suggesting that it is possible to incorporate balance training into it, with plyometric training formulas available to players. In addition, to provide greater stimulation, fitness instructors should modify the structure and sequence of exercises, the amount of training, and the intensity of such training requirements.

Instead of splitting the SAT and balance training, a coach may use a circuit training protocol with two training styles in each circuit, with balance training being an option for resting between separate training sets. Finally, coaches and sports scientists should study whether the integration of rebound training activities into integrated training regimens may improve stability performance on the badminton court. Despite new findings on the influence of mixed training on badminton balance skills, some limitations need to be addressed. Firstly, because most professional badminton players have established immutable tournament and training plans, the study was only able to limit a relatively limited sample size. The second selected an 8-week training period to confirm that the shorter intervention produced good adaptation, as the trial schedule must be acceptable for both coaches and players. However, those seeking research should exercise caution in interpreting and summarizing the current findings.

Conclusions

In conclusion, this study suggests that step aerobic training at a height of 6–8 inches and using a tempo of 130–140 bpm has a 4-week effect on balance, which helps athletes perform better in training and move quickly in a short training period. Future direction, the researchers hope that this study can provide useful information on how to optimize athletes and provide a variety of options for coaches and trainers to use in training programs designed for athletes effectively.

Acknowledgements

There was no funding associated with this study. We would like to thank coaches and athletes for their voluntary participation in the study and for their high commitment to training and testing. I would also like to thank the department of health 9; the ministry of public health Nakhon Ratchasima who provided support for the research instrument in this study.

References

ACSMs Guidelines for exercise testing and prescription.10th ed. (2016) Philadelphia (PA). Lippincott Williams & Wilkins; in press.

Alam, F., Chowdhury, H., Theppadungporn, C., & Subic, A. (2010) Measurements of aerodynamic properties of badminton shuttlecocks. *Procedia Engineering*, 2(2), 2487-2492.https://doi.org/10.1016/j.proeng.2010.04.020.

Asadi, A., Arazi, H., Ramirez-Campillo, R., Moran, J., & Izquierdo, M. (2017) Influence of maturation stage on agility performance gains after plyometric training: a systematic review and meta-analysis. *The Journal of Strength & Conditioning Research*, 31(9), 2609-2617.

Bavli, O. (2016) Investigation into the effects of eight weeks of step aerobic dance practiceon static balance, flexibility and selected basketball skills in young basketball players. *Journal of education and training studies*, 4(5), 233-238.

Bompa, T. O., & Calcina, O. (1993) Periodization of strength: The new wave in strength training. Veritas.Borghuis, J., Hof, A. L., & Lemmink, K. A. P. M. (2008) The importance of sensory-motor control in providing core stability. *Sports Medicine*, 38(11), 893–916, https://doi.org/10.2165/00007256-200838110-00002.

Bouteraa, I., Negra, Y., Shephard, R. J., & Chelly, M. S. (2020) Effects of combined balance and plyometric training on athletic performance in female basketball players. *Journal of Strength and Conditioning Research*, 34(7), 1967–1973. https://doi.org/10.1519/jsc.0000000000002546.

Cabello Manrique, D. (2003) Analysis of the characteristics of competitive badminton. *British Journal of Sports Medicine*, 37(1), 62–66. https://doi.org/10.1136/bjsm.37.1.62.

Chang, W.-D., Chang, W.-Y., Lee, C.-L., & Feng, C.-Y. (2013) Validity and reliability of Wii fit balance board for the assessment of balance of healthy young adults and the elderly. *Journal of Physical Therapy Science*, 25(10), 1251–1253. https://doi.org/10.1589/jpts.25.1251.

Chaouachi, A., Hammami, R., Kaabi, S., Chamari, K., Drinkwater, E. J., & Behm, D. G. (2014) Olympic weightlifting and plyometric training with children provides similar or greater performance improvements than traditional resistance training. *Journal of Strength and Conditioning Research*, 28(6), 1483–1496. https://doi.org/10.1519/jsc.0000000000000305.

Clary, S., Barnes, C., Bemben, D., Knehans, A., & Bemben, M. (2016) Effects of ballates, step aerobics, and walking on balance in women aged 50–75 years. *Journal of sports science & medicine*, 5(3), 390-399.

David G. Behm, Crystal O. Kean, Warren B. (2006) Young fixed foot balance training increases rectus femoris activation during landing and jump height in recreationally active women. *Journal of sports science & medicine*, 5(1), 138.-48.

Dawson, N., Dzurino, D., Karleskint, M., & Tucker, J. (2018) Examining the reliability, correlation, and validity of commonly used assessment tools to measure balance. *Health science reports*, 1(12), e98.

Faude, O., Meyer, T., Rosenberger, F., Fries, M., Huber,G., & Kindermann, W. (2017) Physiological characteristics of badminton match play. *European Journal of Applied Physiology*, 100((4), 479–485. https://doi.org/10.1007/s00421-007-0441-8.

Guinness World Reords. (2017) Fast test badminton Hit in competition (male) retrieved from https://www.guinnessworldrecords.com/world-records/fastest-badminton-hit-in-competition-(male).

Hamed Ibrahim Hassan, I. (2017) The effect of core stability training on dynamic balance and smash stroke performance in badminton players. *International Journal of Sports Science and Physical Education.* 2(3), 44-52.

Hughes, M. G., & Bopf, G. (2005) Relationships between performance in jump tests and speed tests in elite badminton players. *Journal of Sports Sciences*, 23, 194–195.

Kean, C. O., Behm, D. G., & Young, W. B. (2006) Fixed foot balance training increases rectus femoris activation during landing and jump height in recreationally active women. *Journal of sports science & medicine*, 5(1), 138.

Laffaye, G., Phomsoupha, M., & Dor, F. (2015) Changes in the game characteristics of a badminton match: a longitudinal study through the Olympic game finals analysis in men's singles. *Journal of sports science & medicine*, 14(3), 584–590.

Lee, J. J. J., & Loh, W. P. (2019) A state-of-the-art review on badminton lunge attributes. *Computers in biology and medicine*, 108, 213-222. https://doi.org/ 10.1016/j.compbiomed.2019.04.003, 2019.

Lin, S.-I., & Woollacott, M. (2005) Association between sensorimotor function and functional and reactive balance control in the elderly. *Age and ageing*, 34(4),358–363. https://doi.org/10.1093/ageing/afi089.

Lord, S. R., Clark, R. D., & Webster, I. W. (1991) Postural stability and associated physiological factors in a population of aged persons. *Journal of Gerontology*, 46(3), M69–M76. https://doi.org/10.1093/geronj/46.3.m69.

Manouras, N., Papanikolaou, Z., Karatrantou, K., Kouvarakis, P., & Gerodimos, V. (2016) The efficacy of vertical vs. horizontal plyometric training on speed, jumping performance and agility in soccer players. *International Journal of Sports Science & Coaching*, 11(5), 702-709.

Masu, Y., Muramatsu, K., & Hayashi, N. (2014) Characteristics of sway in the center of gravity of badminton players. *Journal of Physical Therapy Science*, 26(11), 1671–1674. https://doi.org/10.1589/jpts.26.1671.

Nithiya, T. N., Saroja S. (2017) Effect of different intensity of step aerobics training on speed and cardiorespiratory endurance among school girls. *International Journal of Current Research and Modern Education*, 2(2), 284-287.

Phomsoupha, M., & Laffaye, G. (2014). The science of badminton game characteristics,

anthropometry, physiology, visual fitness and biomechanics. *Sports Medicine*, 45(4), 473–495. https://doi.org/10.1007/s40279-014-0287-2.

Santos-Rocha, R., Veloso, A., Santos, H., Franco, S., & Pezarat-Correia, P. (2002) Ground reaction forces of step exercise depending on step frequency and bench height. *International society of biomechanics in sports*, 156-158.

Sedigheh, M., Hairul, A.H., Mohamed, R.A., & Mohd, R.M. (2016). The Effects of
supervised step aerobics training combined with daily milk consumption on muscle power and cardiovascular fitness in inactive girls: A Randomised Controlled Trial. International Journal of Collaborative Research on Internal Medicine & Public Health, 8(7), 465-474.

Sekulic, D., Spasic, M., Mirkov, D., Cavar, M., & Sattler, T. (2013) Gender-specific Influences of balance, speed, and power on agility performance. *Journal of Strength and Conditioning Research*, 27(3), 802–811. https://doi.org/10.1519/jsc.0b013e31825c2cb0.

Sturgess, S., & Newton, R. U. (2008) Design and implementation of a specific strength program for
badminton. *Strength & Conditioning Journal*, 30(3), 33-41.

Tiwari, L. M., Rai, V., & Srinet, S. (2011) Relationship of selected motor fitness components with the performance of badminton player. *Asian journal of physical education and computer science in sports*, 5(1), 88-91.

Yung, P. S. H., Chan, R. H. K., Wong, F. C. Y., Cheuk, P. W. L., & Fong, D. T. P. (2007) Epidemiology of injuries in Hong Kong elite badminton athletes. *Research in Sports Medicine*, 15(2), 133-146.

Datos de los/as autores/as y traductor/a:

Ashira Hiruntrakul	hashir@kku.ac.th	Autor/a – Traductor/a
Chittraporn Thongkong	nhunewprim@gmail.com	Autor/a
Charee Jansupom	charee.ch@rmuti.ac.th	Autor/a
Nur Azis Rohmansyah	nurazisrohmansyah@uny.ac.id	Autor/a
Neranoch Bumrung	Neranochh@kkumail.com	Autor/a