**EFFECT OF STRUCTURED RAMP WARM-UP PROTOCOL ON IMPROVING BADMINTON PLAYERS FOOTWORK PERFORMANCE**

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**2023**

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**SUBMITTED TO THE FACULTY OF SPORT AND EXERCISE SCIENCE UNIVERSITI MALAYA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF STRENGTH AND CONDITIONING(MSC)**

**2023**

**UNIVERSITI MALAYA**

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**EFFECT OF STRUCTURED RAMP WARM-UP PROTOCOL ON IMPROVING BADMINTON PLAYERS FOOTWORK PERFORMANCE**

ABSTRACT

The purpose of this study is to determine and develop and test the effectiveness of a structured RAMP (Raise, Activate, Mobilize, Potentiate) warm-up targeting badminton footwork performance. This study investigates the impact of a structured RAMP warm-up protocol on badminton footwork performance. The research involved 18 participants (9 males and 9 females), aged 18-34 years. A randomized crossover design was employed, comparing the effects of structured and unstructured warm-ups on footwork agility and reaction time. Results indicate that the structured warm-up significantly improved footwork performance, reflected by increase of 2.74%, from 23.75±1.25 to 24.40±1.60 in hits and a decrease of 1.57%, from 2358.40ms ±146.30 to 2321.4ms ±157.00 in reaction time. These findings suggest that the structured RAMP warm-up can enhance both physical and neuromuscular readiness, improving agility and decision-making capabilities. The incorporation of the BlazePod system facilitated objective assessment and validate agility test specifically for badminton footwork performance. The findings hold implications for athletes, coaches, and researchers, emphasizing the significance of structured warm-up routines in improving badminton footwork performance.

**Keywords**: Badminton, Footwork, RAMP warm-up, Agility, BlazePod

**KESAN PROTOKOL PEMANASAN TANJUNG BERSTRUKTUR TERHADAP MENINGKATKAN PRESTASI KERJA KAKI PEMAIN BADMINTON**

ABSTRAK

Kajian ini dilaksanakan dengan tujuan untuk membangun serta menguji keberkesanan protokol pemanasan berstruktur RAMP (Raise, Activate, Mobilize, Potentiate) yang mensasarkan kepada prestasi gerak kaki pemain badminton. Kajian ini melibatkan sejumlah 18 peserta yang terdiri daripada 9 peserta lelaki dan 9 peserta perempuan yang berusia antara 18-34 tahun. Teknik pensampelan secara rawak bersilang (randomized crossover) digunakan untuk membandingkan kesan pemanasan (warm-up) secara berstruktur dengan tidak berstruktur terhadap masa tindakbalas serta kelincahan pergerakan kaki peserta. Keputusan kajian menunjukkan bahawa peserta yang melakukan pemanasan secara berstruktur menunjukkan peningkatan terhadap prestasi gerak kaki. Ini terbukti dengan peningkatan sebanyak 2.74%, daripada 23.75±1.25 to 24.40±1.60 terhadap pukulan bulu tangkis serta pengurangan masa tindakbalas sebanyak 1.57% daripada 2358.40ms ±146.30 kepada 2321.4ms ±157.00. Hasil kajian ini membuktikan bahawa teknik pemasanan berstruktur RAMP berupaya untuk meningkatkan tahap kesediaan fizikal serta neuro otot, sekaligus mengingkatkan tahap ketangkasan dan keupayaan membuat keputusan. Penggabungan sistem BlazePod memudahkan penilaian objektif dan mengesahkan ujian ketangkasan khususnya untuk prestasi kaki pemain badminton. Hasil kajian ini memberi implikasi kepada atlit, jurulatih serta pengkaji untuk memberi penekanan kepada program pemanasan secara berstruktur di dalam meningkatkan prestasi pemain badminton.

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to my supervisor, Dr. Eliza Binti Hafiz, for her invaluable guidance throughout this research project. Her knowledge, patience, and unwavering support have all played a role in shaping the direction and quality of this research.

I am also grateful to the research participants, whose willingness to devote their time and efforts made this study a reality. Their enthusiasm, cooperation, and valuable insights have greatly enriched the research findings and outcomes.

We also acknowledge the invaluable support provided by Babel academy. The use of the BlazePod system for assessment purposes significantly contributed to the accuracy and depth of our findings.

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LIST OF SYMBOLS AND ABBREVIATIONS

|  |  |  |  |
| --- | --- | --- | --- |
| BVR | : | band variable resistance | |
| CMJ | : | Countermovement jump | |
| COD | : | Change of direction | |
| CODS | : | Change of direction speed | |
| CON | : | Control |  |
| DS | : | Dynamic stretching | |
| DSW/DW | : | Dynamic warm-up | |
| EBW | : | Elastic band warm-up | |
| FW | : | Footwork |  |
| HL | : | Heavy load leg press | |
| HRW | : | High-resistance warm-up | |
| IM-specific | : | Inspiratory muscle-specific | |
| LL | : | Lower limit |  |
| LWU | : | Loaded warm up | |
| M | : | Mean |  |
| NWU | : | Neuromuscular warm-up | |
| PAP | : | Post-activation potentiation | |
| PLA | : | placebo |  |
| RAMP | : | Raise, Activate, Mobilize, and Potentiate | |
| ROM | : | Range of motion | |
| RT | : | Reaction time | |
| SD | : | Standard deviation | |
| SV | : | Smash velocity | |
| UL | : | Upper Limit |  |
| VFR | : | Vibration foam rolling | |
| WWR | : | Weighted wearable resistance | |

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# INTRODUCTION

Badminton is a tactical sport that requires a high level of coordination ability in the lower body to sustain a rally (Seth, 2016). Players need to execute one shot while accelerating, decelerating, and changing direction toward the centre of the court and to the opponents' return shot (Loturco, et al., 2022). Athletes who can move quickly, change directions, and execute continuous jumps, sudden stops, and activations are better able to maximise their technical performance and win in a rally (Kuo, 2020). Players' ability to change the direction of their whole body movement and reaction times (Cheng et al., 2006; Loureiro Jr. & de Freitas, 2012) are crucial for success in this sport because each shot made by the opponent is unpredictable (Tiwari et al., 2011).

Agility is defined as a ''rapid whole-body movement with a change in velocity or direction in response to a stimulus.'' (Young, Dawson & Henry, 2015), the key phrase in this definition is "response to a stimulus," which implies that agility includes not only the ability to change directions physically but also the ability to make decisions about when and where to change directions (Paterson et al., 2016). Where change of direction (COD) is the ability to change direction quickly and effectively, which inferring that agility must involve a reaction to a stimulus and CODS (Young , Rayner & Talpey, 2021).

Since a badminton game is composed of unpredictable rallies, having fast CODS does not imply the athlete must have fast agility. Therefore, “agility” instead of simply “COD” should be considered when determining one’s footwork performance. Previous research suggested that CODS is considered one of the essential footwork performance predictors (Hughes & Cosgrove, 2006), proving that researching the best method e.g. implementing a structured warm-up protocol for acute COD augmentation is likely to improve badminton performance, however, the cognitive component was overlooked. Therefore, in this study, agility, instead of COD was considered.

In badminton, footwork speed is also determined by reaction speed of players to starting a movement, which is also known as activation speed (Kuo, et al., 2020). having a fast reaction speed which means player can activate, anticipate and response to a stimulus quickly, which is known as agility (Kuo, et al., 2020). With faster reaction time and agility, badminton players can have a faster and efficient footwork.

To acutely enhance footwork performance, one of the ways is by designing a proper and structured warm-up (Jeffreys, 2021), to prepare athletes physically and mentally better for upcoming matches or training. Implementing a well-designed warm-up protocol is a common method used to improve performance and reduce the risk of injury in a variety of sports (Sole, et al., 2013; Fernandez-Fernandez, 2020). It has also been shown that certain warm-up activity like loaded warm-up has significant effect on force development, which could improve CODS (Maloney, etl al., 2014). Whereas the RAMP (Raise, Activate, Mobilize, and Potentiate) system is one of the approached used to design a structured warm-up for improving badminton footwork performance, which enables athletes to provide their best effort during practice or competition. Stronger athletes can be built logically, methodically, and effectively with the help of a structured RAMP warm-up (Jeffreys, 2019).

The "RAMP" approach offers a structured foundation to create efficient warm-up routines for both competitions and workouts. By incorporating skill-based *raise* sections, athletes can engage in significant skill or movement development warm-up movements without adding extra time to their training schedule. Similarly, *activation and mobilization* activities allow for effective mobility and prehab training without requiring additional time. Furthermore, the *potentiation* phase of the warm-up presents an ideal opportunity to include activities such as loaded speed and agility work , which induces the post-activation potentiation (PAP) effect to prepare the athlete more adequately for the main session, especially when high-intensity activities are involved. (Jeffreys, 2021).

Recently, the concept of post-activation potentiation (PAP), which is the short-term enhancement of peak force and rate of force development, has been incorporated into warm-up routines to maximize motor unit and brain recruitment prior to criterion performance (Marshall, et al., 2019), which is the major aim of conducting a warm-up, however this can only be achieved by a well-planned and structured warm- up based on scientific evidence. One of the ways is using a RAMP system. By strategically incorporating all the components above into the warm-up, athletes can optimize their preparation for training and competitions without extending the overall time commitment (Jeffrey, 2019).

According to Jeffereys (2019) and McGowan, et al. (2015), the veracity of the matter is that athletes and coaches frequently adhere to conventional practices. The intensity and duration of the physical tasks completed, as well as the length of the transition phase, determine the effectiveness of an active warm-up strategy (McGowan et al., 2015). The traditional warm-up routine, stretching and sport- specific activities are typically performed after a brief period of low-intensity exercise (Safran, et al., 1989). Correspondingly, when queried about the rationale behind warming up, coaches and athletes commonly offer generalized explanations, primarily emphasizing either the reduction of injury risk or the enhancement of subsequent performance (Jefferys, 2019). It is also notable that although warming up is widely acknowledged as an essential aspect of every training session, there is surprisingly little high-quality research particularly on badminton warm- up practices (Jeffereys, 2019). As a result, many accepted practices are based on personal experiences which is non-structured rather than scientific evidence not to mention having it well-designed and well-structured (Jeffereys, 2019). To reduce the likelihood of tearing muscle fibres, sufficient and well-planned warm up should be done (Pelmuş, 2020).

To evaluate the effectiveness of structured RAMP warm-up protocol, specific agility test is needed to determine the footwork performance of a badminton player. As mentioned earlier, COD tests focuses solely on physical ability and is typically performed in pre-planned environments, whereas agility involves reactive abilities (e.g., visual processing, perception, anticipation, etc.) in unpredictable environments. In badminton games, players always face unpredictable and unplanned shots, therefore, traditional agility tests like T-test, Illinois agility test, arrowhead agility test, and pro-agility test are incapable of measuring agility in badminton players because these tests do not mimic the gameplay nature of badminton matches since they consists of unpredictable stimulus, instead they require an athlete to complete a pre-planned course of directional changes as quickly as possible, which is not actually a measure of agility, but instead a measure of ‘change of direction speed’.

There was a specific on-court COD test developed in 1995 by Chin, et al., validate by Fernandez- Fernandez in 2022 will be used to test for badminton player’s footwork performance in this study. The results will be recorded by BlazePodTM , which is a new technology developed for measuring reaction time (RT), will be used as a testing tool for badminton players’ footwork performance in this research. It was suggested in research that the BlazePodTM technology provides reliable information (de-Oliveira, et al., 2021). The validity for using BlazePodTM was proved only in research for other sports including football (Hoofman, 2020; Kim, et al,2021), handball and volleyball (Kim et al., 2021), no research has been done with badminton. Therefore, this will also be the first research for badminton using BlazePodTM as an assessment specifically for badminton athletes.

The purpose of this study is to determine and develop and test the effectiveness of a structured RAMP warm-up targeting badminton footwork performance. Thus, providing guidelines for a structural and sequenced warm-up routine customized to badminton players seeking to enhance their footwork performance.

* 1. **Problem statement**

Despite research demonstrating the effectiveness of particular warm-up activities on badminton footwork performance, no research has suggested a comprehensive protocol and warm-up sequence to guide coaches and players throughout their entire warm-up session. Based on a previous research (Bishop, 2019), there is lack of specific and effective warm-up protocol for badminton athletes’ footwork performance. As a result, coaches need to create their own customized warm-up routines based on individual experiences, which is not scientific (Jeffreys, 2019; McGowan, 2015). Unlike football, where FIFA 11+ is available for coaches and athletes to take as reference, there are very few research suggesting warm-up activities to improve badminton footwork performance, not to mention a holistic warm-up protocol for badminton athletes.

* 1. **Research question**

Does a structured RAMP warm-up lead to significant difference in badminton footwork performance?

* 1. **Research objective**

To determine the effectiveness of structured RAMP warm-up on footwork performance.

* 1. **Research Hypothesis**

H0: there are no significant difference on the effect of a structured and non-structured warm-up on badminton footwork performance.

H1: There are significant differences on the effect of a structured and non-structured warm-up on badminton footwork performance.

# LITERATURE REVIEW

## Footwork in badminton

Badminton footwork encompasses movement towards six directions on the court, including to the right and left frontcourt, the right and left midcourt, and the right and left backcourt (Chiu, et al., 2020). The players typically have less than one second to react and run in anticipation of the shuttlecock's direction due to the shuttlecock's brief movement time during the rally. A professional player therefore essentially needs to have a higher level of reaction speed, agility to react and anticipate the opponent's shot (Rusdiana, 2021).

Badminton footwork is crucial in badminton as it provides a solid foundation for the body, enabling precise and powerful movements. Agile and swift footwork plays a pivotal role in returning the opponent's shuttlecock with superior techniques and the ability to place the shuttlecock in challenging spots (Subarkah, 2018). It allows players to reach even the most difficult shots from their opponents. Consequently, top-notch footwork is a fundamental requirement for any skilled badminton player (Subarkah, 2018). It is also agreed by Chen (2014) that the significance of Badminton Footwork as a crucial component of badminton skills. Learning and perfecting the swift and precise techniques play a vital role in establishing a strong foundation for mastering badminton.

## Key factors and measurements of footwork performance in badminton

### Factors affecting footwork efficiency

#### Agility

Badminton footwork is affected by several factors shown in figure 2.1. Agility is one of the essential elements that affect footwork performance (Kuo, 2020; Loureiro Jr, et al., 2017). Agility is the ability of the body to change direction quickly during a movement while maintaining body balance (Rusdiana, 2021). Having a good footwork is advantageous in both attacking and defending since the returning of shuttlecock is unpredictable(Paterson, 2016). The change in the player's movement direction is difficult to plan because it is dependent on the shuttlecock direction of the opponent's shot (Rusdiana, 2021).

Despite the importance of agility in badminton footwork, previous research on badminton footwork performance mostly focused on COD instead of agility (Jeyaraman, District & Nadu, 2012; Tiwari, et al., 2011; Yeung, et al., 2021; Chua,et al., 2021) it was mainly due to the unclear definition of COD and agility used in those research. It is defined by Sheppard and Young (2006) that agility is “a rapid whole-body movement with change of velocity or direction in response to a stimulus”, which means “COD” together with a “response to stimulus” create “agility”. Even though COD is an important skill in badminton, it may not be a direct indicator of badminton footwork performance. This is because badminton players have to react to different unpredictable return shots from their opponent, requiring rapid response to stimulus, adjustments in , movement and positioning. Agility encompasses a broader set of skills, including cognitive component, while COD does not.

#### Reaction time (RT)

The amount of time that passes between the occurrence of a stimulus and the start of a movement is known as the RT (Prabhu, 2022). Since the speed of a shuttlecock is very fast, less than a second, high concentration and fast reaction is required in making a decision in order to respond to stimuli quickly and accurately during a game (Rusdiana, 2021).

In badminton, RT is inextricably linked with anticipation—predicting an opponent's shot based on visual cues. According to a study conducted by Bakosz, Nawara, and Ociepa (2013), players with exceptional RT tend to anticipate shots accurately, giving them a strategic advantage by positioning themselves proactively. This anticipation improves a player's ability to intercept shots. Players with faster RTs make better decisions, allowing them to change their footwork pattern in response to changing shot trajectories. This adaptability aids in maintaining court control and effectively responding to opponents' unpredictable shots.

In a recent research involving badminton players,  expert and nonexpert players were compared in a reactive task that required pointing targets on a touchscreen as quickly and precisely as possible (Loureiro & de Freitas, 2012). The findings indicated that expert players demonstrated quicker RT compared to nonexperts. However, there were no significant differences in movement time or accuracy levels between the two groups. These outcomes suggested that RT for processing visual information might play a significant role in distinguishing the performance levels of badminton players (Loureiro & de Freitas, 2012).

#### Technique, anthropometry, coordination, balance, flexibility, aerobic capacity

These components also affect badminton footwork but cannot be corrected with just simply warm-up (Kim, et al., 2014; ), long term intervention are needed. Therefore will not be thoroughly discussed.

However, it is still important to briefly understand their effects on footwork performance.

According to Subarkah & Novitaria (2018), technique is important in badminton footwork. Due to its role in the game, the footwork in badminton acts as a foundational support, enabling players to position their bodies optimally and reach the shuttlecock earlier for effective striking motions.

Secondly, anthropometric measurements show information about a player's height, arm span, body composition, and other relevant physical characteristics. Footwork performance is also affected by the characteristics of the players. Players with longer arm spans, for example, may have an advantage when executing long-reaching shots or serves. Shorter players may excel in agility and quick footwork (Phomsoupha & Laffaye, 2015).

Thirdly, Coordination is the ability to effectively synchronise body movements. Exact coordination is required in badminton to execute various shots, footwork patterns, and court positioning (Woodward, 2017). Because of the constant need to change direction, lunge, and perform explosive movements, balance is essential in badminton. Maintaining balance allows players to move quickly while being ready for sudden changes in momentum (Hung et al., 2020). Flexible joints and muscles allow for smoother footwork, allowing players to move quickly around the court while putting less strain on their bodies (Woodward, 2017).

Lastly, badminton is a physically demanding sport that requires high-intensity bursts interspersed with periods of moderate activity. Players with good aerobic stamina can endure long matches while maintaining a high level of footwork performance. Improved stamina reduces fatigue, allows players to remain effective during long rallies (Lin et al., 2007).

**Figure 2.1 Factors affecting badminton footwork performance**

Note: This model was produced by referencing to Young, W. B., Dawson, B., & Henry, G. J. (2015). Agility and change-of-direction speed are independent skills: Implications for training for agility in invasion sports. International Journal of Sports Science & Coaching, 10(1), 159-169; Paterson, S., McMaster, D. T., & Cronin, J. (2016). Assessing change of direction ability in badminton athletes. Strength and Conditioning Journal, 38(5), 18-30. And Malwanage, K. T., Senadheera, V. V., & Dassanayake, T. L. (2022). Effect of balance training on footwork performance in badminton: An interventional study. PloS one, 17(11), e0277775. <https://doi.org/10.1371/journal.pone.0277775>

## Assessing footwork performance in badminton

A significant correlation has been found between athletic performance and the agility of footwork movements (Chiu et al., 2022; Latorre et al., 2020). Agility is defined as a rapid whole-body movement with a direction or speed change in response to a stimulus. Traditional agility tests, however, do not address this definition and are pre-planned with no stimulus. specific agility test for badminton should be used since it would be a more effective and exclusive agility test method than traditional and general agility tests (Kuo, 2022).

Tests requiring pre-planned movements should be classified as COD tests rather than agility tests (Loureiro & de Freitas, 2016). In various research, agility was mainly tested with general tests, including the agility T-test, 5-0-5 COD test. These tests are done without cognitive components which means that they are simply testing for COD only.

It should be noted that badminton footwork is very specific. To accurately test for badminton footwork performance, a test that simulates the precise direction changes required for badminton could help distinguish between poor and good movement patterns (Paterson et al., 2016). Even though there were research suggesting testing for badminton performance, majority of them are just testing for CODS as well (Maloney, 2014; Paterson, 2016).

The research that uses specific field testing for badminton footwork was developed back in 1995 by Chin, et al. it was retested and validated by Kusuma (2015), Loureiro & de Freitas (2016) and Fernandez-Fernandez, et al. (2022) and it was found that this test was more valid and reliable than general agility tests (Kusuma, 2015).

The original test involves lamp (Chin, et al., 1995) or photocells (Fernandez-Fernandez, et al., 2022) connecting to programming device located outside the court which makes the set up more hectic and complicated. With improved technology, footwork performance can be tested directly with the set of reaction lights (BlazePodTM) and measurements can be seen directly through the mobile app connected with it.

Current approaches to assess footwork performance on the badminton court are still in their early stages. Usually, only the overall time taken to complete the six-direction footwork is measured using a stopwatch, without gathering more comprehensive data, such as the speed of movement in each direction (McGinnis, et al., 2017). In addition, for various directions, different stepping and lunging techniques as well as arm movements may be used. The two frontcourts are relatively easier to reach as moving forward is more instinctive than moving backward. At two sides of the court, players may move with different steps, either cross-step or chase-step. As a result, each player may not be able to execute the 6-point footwork in the same manner. It becomes crucial to evaluate each direction's footwork performance (Chiu, et al., 2020).

### BlazePodTM: An Innovative Tool for Performance Measurement

To assess badminton footwork, we need to assess agility and CODS, since they are the most important factors affecting badminton footwork and could be acutely altered by well-designed warm-up.

To differentiate agility and COD test, one important parameter is RT. Since it is affected by various visual stimulation and depends very much on cognitive decision making, BlazePodTM is a reaction light device that provide visual stimulus and record RT (de-Oliveira, et al., 2021). It is an innovative device that employs interactive lights and sensors to create a dynamic training or testing environment. The system is made up of small, portable pods that can be placed on the ground or attached to various objects like walls or cones.

The device tracks the player's RT, speed, and accuracy during these agility exercises, providing valuable data for performance analysis and improvement (Hoofman, 2020). It also allows coaches and players to set customizable training programs and monitor progress over time (de-Oliveira, et al., 2021).

It was suggested in research that the BlazePodTM technology provides reliable information (de-Oliveira, et al., 2021). The validity for using BlazePodTM was proved in research for different sports that requires a lot of agility including football (Hoofman, 2020; Kim, et al,2021), handball and volleyball (Kim et al., 2021).

## Warm-up protocols in badminton

Warm-up has been playing an important role in improving sports performance but most research relating to the effect of warm-up on performance did not specify the type of sports that the participants were doing (Chatzopoulos, 2014; Chaouachi A, 2010; Escobar, 2021; Cigerci, 2023), so it is hard to draw a specific conclusion for the studies since the different types of sports varies differently. Also, most research investigating the effect of warm-up on performance are related to football (Ayala, 2017; Hoofman, 2021; Asgari, 2022; Kurt, 2016; Tarha, 2016; Constantino Coledam, 2009), tennis (Kilit B, 2019; Fernandez-Fernandez, 2020; Moreno-Pérez, 2021; Lopez-Samanes, 2021). In order to lower injuries among male and female football players aged 14 and over, F-MARC (2013) and experts in the field of football medicine developed the FIFA 11+, a thorough warm-up programme (Owoeye, et al., 2014). Unfortunately, there doesn't seem to be much of this kind of programme being implemented in the badminton community (Rangasamy, et al., 2022; Mao., 2019).

Only 6 research were done to investigate the effects of different warm-up activities on badminton footwork (Lin, et al., 2007; Yeung, et al., 2021; Maloney, Turner, & Miller., 2014; Lin, Lee, & Chang., 2020; Kwon, et al., 2022; Chua, et al, 2021) (table 2.1).

Table 2.1 shows the summary of warm-up effects on improving badminton COD. However, the numbers of research specifically for badminton is very few, other research regarding the warm- up effect on COD were taken as reference to develop a more holistic protocol. Table 2.2 shows summary of warm-up effects on improving COD in other racket sports that also requires a lot of change of direction speed and agility in their footwork. to improve badminton athletes' court performance, and it is discovered that warm-ups such as Inspiratory muscle (IM) -specific warm-up, loaded warm- up (LWU), dynamic stretching (DS) and neuromuscular warm-up (NWU) could be effective for improving badminton players' footwork performance, since these research has shown that the activities can significantly improve COD performance (p<0.05).

**Table 2.1Summary of warm-up effects on improving badminton COD and lower limbs speed**

| No. | Authors and year | Study target/target population | Test method/warm-up protocol | Outcome measures | Main finding | Degree of improvement | Comment |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | Lin, et al., 2007. Specific inspiratory muscle warm-up enhances badminton footwork performance. | 10 male badminton players were chosen at random to undergo identical tests in three different trials; IM-specific warm-up (IMW) vs Placebo (PLA) | PLA :two sets of 30-breath manoeuvres with an inspiratory pressure-threshold load comparable to 15% maximum inspiratory mouth pressure  IMW: 40% | Footwork performance: (FW)max  Rating of perceived breathlessness for every minute (RPB/min) | IM-specific warm-up ↑ footwork performance.  The influence of the accompanying reduction in [La-]b buildup was minimal. | FWmax ↑ 6.8% ± 3.7% | The integrated warm-up protocol in IMW but not in PLA.  The improved footwork was due in part to the reduced breathlessness caused by the increased IM function |
| 2 | Yeung, et al., 2021. Does a Loaded Warm-Up Influence Jump Asymmetry and Badminton-Specific Change of Direction Performance? | Two trials were completed by a total of 21 amateur badminton players (29.5 yrs old, playing experience 8.4 yrs); Effect of 3 exercises loaded with a weight vest on CODS | 1st group: control, 2nd group: repeated the warm-up but added three exercises loaded with a weight vest (LWU) of 10% body mass. Players conducted single-leg countermovement jump (CMJ) and badminton-specific COD tests after both warm-ups. | CODS  single-leg improvement in CMJ  Improvement in single-leg CMJ asymmetry | There were no significant differences in CODS, CMJ. | No improvement was observed | LWU had no significant influence on performance or asymmetry. |
| 3 | Maloney, Turner, & Miller., 2014. Acute effects of a loaded warm-up protocol on change of direction speed in professional badminton players. | 8 elite badminton players took part in 3 sessions, which include vertical CMJ and CODS testing before and after the dynamic warm-up; Effect of loaded warm up on COD | The three warm-up with weighted vest of:(a) 5% body mass, (b) 10% body mass, and (c) no weighted vest. vertical jump and CODS were then assessed at 15s, 2, 4, and 6 mins after the warm-up. | Pre- and post-warm-up Vertical jump and CODS performance  in 3 different conditions | there was no major effect of condition, time, or interaction effect on mean vertical jump performance.  CODS Peak performances were substantially faster in the 10% loaded condition | significantly faster peak performance in the 10% loaded condition (5%; ES = 0.83; P = .012) | Following a loaded warm-up, elite badminton players performed noticeably higher in the CODS test.  compared to an unloaded warm-up, the loaded warm-up did not significantly affect vertical jump performance. |
| 4 | Lin, Lee, & Chang., 2020. Acute Effects of Dynamic Stretching Followed by Vibration Foam Rolling on Sports Performance of Badminton Athletes. | 40 badminton players (25 male,15 female college students), no incidence of musculoskeletal disorder in the preceding 6 months; Dynamic stretching (DS) vs vibration foam rolling (VFR) | Two protocols: (1) DS; (2) DS followed by vibration foam rolling (VFR)  Each subject carried out the two protocols separately, in a randomized order, separated by a 48-hour period. | Knee range of motion (ROM) Muscle stiffness Lower limb power  Agility | DS ↑ knee flexion ROM, CMJ and agility but ↑quadriceps muscle stiffness and ↑ gastrocnemius muscle stiffness.  DS + VFR ↑ knee extension ROM, ↓ quadriceps muscle stiffness, CMJ height, agility | Agility 4.74% faster,  CMJ height ↑ 2.41% | Both protocols also improves performance.  DS can be considered as the first line of warm-up exercise to increase ROM, CMJ height, and agility. |
| 5 | Kwon, et al., 2022. The Effect of Warm up type on Physical Fitness factor related to Badminton Players Performance. | 10 female college badminton players. subjects were randomly assigned to dynamic warm-up (DSW), elastic band warm-up (EBW), non-warm-up exercise (CON) at 2-w interval. | Crossover research was carried out to investigate the impact of the warm-up program. | Range of motion (flexion, abduction, external rotation, internal rotation) agility (Agility-t test) muscle power (CMJ) | Results of abduction, external rotation, internal rotation, agility, and muscle power were not statistically significant. | No improvement was observed | Further investigation on program for agility improvement is needed. The insignificance might be due to the small sample size. |
| 6 | Chua, et al, 2021. Effectiveness of On-Court Resistive Warm-Ups on Change of Direction Speed and Smash Velocity during a Simulated Badminton Match Play in Well-Trained Players. | 14 national training squad badminton players (11 males, 3 females ) completed the experimental sessions in random order; Effect of control (CON), weighted wearable resistance (WWR), and resistance band variable resistance (BVR) on CODS and smash velocity | A repeated-measures approach was used in this investigation, with three warm-up conditions: CON, WWR and BVR. | Change of direction speed (CODS)  Smash velocity (SV) at 5 timepoints | CODS was faster under the two resistance warm-up conditions.  SV was considerably quicker than at baseline for all four workout blocks but there were no changes in SV across the 3 warm-up in all 5 assessed timepoints. | Improvement of 1.38% in CODS with WWR, Improvement in 0.41% with BVR | When compared to the same warm-up exercises using bodyweight, adding resistance (10% body weight) in sport-specific plyometric activities employing WWR or BVR during warm-up routines may elicit PAPE effects on change of direction speed but not smash velocity in well-trained badminton players. |

**Table 2.2 Summary of warm-up effects on improving COD and agility in other racket sports**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Authors and year | Study target/target population | Test method/warm-up protocol | Outcome measures | Main finding | Degree of improvement | comment |
| 1 | Sole, et al., 2013. Mechanical analysis of the acute effects of a heavy resistance exercise warm-up on agility performance in court-sport athletes | 5 men and 5 women were involved in the study. All of the subjects were Division II athletes participated in tennis or basketball; evaluate the acute effects of a heavy resistance exercise warm-up on agility performance | counterbalanced design: examine agility performance during a 10m shuttle test after dynamic warm-up (DW) or a high resistance warm-up (HRW) protocol. HRW protocol: 3 sets of squats at 50, 60, 90% 1RM. | Agility performance  Stride length  Stride frequency Stance time  Flight time  Average ground reaction force  Agility time | There were no significant differences between the HRW and DW procedures (p>0.05) | No improvement was observed | The insignificance results could be due to the small sample size. As well as the different nature of sports of tennis and basketball may related to the inconclusive results |
| 2 | Fernandez- Fernandez, 2020.  The Effect of a Neuromuscular vs. Dynamic Warm-up on Physical Performance in Young Tennis Players. | 28 skilled male tennis players. This study aim to compare the effects of a neuromuscular warm-up and a dynamic warm-up on physical performance measures in young tennis players | Players were randomly assigned to one group: neuromuscular warm-up (NWU) group or dynamic warm-up (CON) group, for 8 weeks.  NWU: focused on improving neuromuscular CON: exercises that involved dynamic movements to increase core temperature and flexibility. | Agility (5-0-5 COD test)  Sprint speed  Serve speed  Jump height (CMJ)  Medicine Ball throw distance  Shoulder ROM | both the NWU and DWU: significant improvements in sprinting (5-20m) (p < 0.05)  bilateral+unilateral CMJ (p < 0.005)  overhead medicine ball throws (p = 0.014  range of motion measures (p < 0.05). | NWU:  1.8s improvement in agility test  4.6cm improvement in CMJ | From interaction effect, NWU yielded better performance gains in most of the investigated parameters.  The study only included 28 young tennis players, may have ↓  statistical power to identify significant variations in serve speed between the groups. It may be necessary to do another research with a bigger sample size to ascertain the impact of various warm-up |
| 3 | Lopez-Samanes, et al., 2021. Acute effects of dynamic versus foam rolling warm-up strategies on physical performance in elite tennis players | 11 elite men tennis players. Participants were ranked in the Association Tennis Professionals and within the top 300 players in Spain. All of them are playing at a competitive level | Each group performed assigned warm-up protocol for 10 min before assessing physical performance.  participants completed these tests twice, with 30-min rest interval between tests. The order of the tests was randomized. | CMJ height  10-meter sprint speed  Agility (T-test) | Both groups showed +change but DS warm-up resulted in + improvement in CMJ and agility T-test but not in 10m sprinting.  foam rolling 🡪 improvements in CMJ only and 10m sprint performance, but not in agility T-test performance. | DWU:  CMJ:+2.32%  10-m sprint: -1.26%  505 agility: -2.63%  SMFR  CMJ:+0.61%  10-m sprint: +1.03%  505 agility: +0.44% | Self-myofascial release during a warm-up period of a workout is probably not improving performance..  DWU provided greater training for sprint and change of direction movements, high-performance tennis players should incorporate DS into their warm-up. |
| 4 | Moreno-Pérez, et al., 2021.  Post-activation performance enhancement of dynamic stretching and heavy load warm-up strategies in elite tennis players | 26 elite male tennis players 🡪evaluate potential impacts of two warm-up techniques: DS and heavy load leg press (HL), on a number of important physical characteristics in tennis players. | Participants completed both warm-ups in a randomised order, with 48hr between the DS and HL. Pre- and post-tests were conducted before and after the DS and HL warm-up regimens | 5m and 10m sprint speed  5-0-5 agility  hip extension hip flexion ROM | All tests showed significant improvements after DS warm-up  HL warm-up impaired 5m and 10m sprint but showed positive improvements in other test | DS  5m sprint: -2.1%  10m sprint: -1.8%  505-agility: 3.7%  HL  5m sprint: 0.7%  10m sprint: -0.5%  505-agility: 3.7% | DS warm-up suggested in the research is effective in improving CMJ, 5-m and 10 m-sprint and 5-0-5 agility test |
| 5 | Kilit, et al., 2019.  Effects of different stretching methods on speed and agility performance in young tennis players. | 26 young tennis players were recruited in this study, to find out the acute effect of different stretching methods on speed and agility performance in young tennis players | Participants divided into 5 groups: static, dynamic, static + dynamic, dynamic + static, and control.  Protocol: 8-min warm-up, 3-min rest, 30-s stretching, 2-min rest, 🡪 T-drill agility and 20m sprint test | 10m acceleration time  20m sprint test  Agility test time | acute effect of static stretching negatively affect agility and sprint performances | No improvement was observed | Static stretching should not be included in warm-up protocol. DS/DS+SS might be better use for better performance in acceleration ,speed and agility skills. |

#### 2.4.1 Inspiratory muscle (IM)-Specific warm-up

IM-specific warm-up are warm-up activities for inspiratory muscles and usually done with using a airflow restriction device. Exercise tolerance was increased as a result of the improved dynamic IM function brought on by the addition of the IM warm-up activity (Lin, et al., 2007).

In badminton, additional IM effort is required to stabilise the chest to facilitate badminton stroke execution (Lin et al., 2007). Lin (2007) was the only research that study the effect of IM-specific warm-up on badminton, also is the only study that investigate the effect of warm-up on blood lactate level in badminton players nad it was found that IM-specific warm-up was effective to improve badminton footwork performance (p<0.05). Therefore, IM-specific warm-up plays a unique role in badminton warm- up routine.

It is also agreed in another study (Mackała, et al., 2020) for soccer players that IM-specific warm- up (two sets of 30-breath manoeuvres with inspiratory pressure threshold equivalent to 40% maximum inspiratory mouth pressure) could be beneficial to reduce breathless sensation in following intense exercise via IM functional capacity enhancement, decrease blood lactate concentration thus increase exercise tolerance. Therefore, it allows athletes to perform footwork in more energy-efficient way.

#### 2.4.2 Dynamic Stretching (DS)

Various research has been done on discussing the effectiveness of DS on badminton (Lin, et al., 2020; Jang, et al., 2017). It has been widely proven that a dynamic warm-up causes acute enhancements in speed/power performance. However, adding specific "preconditioning" exercises, such as front/back lunges which are frequently used in badminton footwork, to a warm-up may further boost performance gains (Yeung, et al., 2021).

There are many types of DS can be done, the types of DS suggested by Moreno-Pérez, et al., (2021) included straight leg march, forward lunge with opposite arm reach, forward lunge with an elbow instep, lateral lunge, trunk rotations, multi-directional skipping. It was effective to positively affect agility. It was also agreed in the study done by Kilit el al., 2019 that DS is effective way to improve agility when compared to static stretching. Increased muscle blood flow and temperature (thixotropic effects on tissue viscoelasticity), neural activation, nerve conduction velocity, and elevated core or peripheral temperature may all be attributed to the DS warm-up protocol (Jefferys, 2019) .

In addition, it is suggested that performance enhancement after dynamic stretching is related to Post-activation potentiation (PAP). PAP is the improvement of muscle function as a direct result of its contractile history, can be used to improve peak performance. The fundamental idea behind PAP is to engage in a certain activity that is intended to maximise motor unit and neuronal recruitment before performance (Maloney, et al., 2014).

#### 2.4.3 Loaded warm-up (LWU)

LWU is dynamic warm-up mostly performed with weighted vest (Maloney, et al., 2014a). Loaded with 10% of the body weight to dynamic warm-up further induce PAP thus potentiating footwork. As mentioned previously, inducing PAP is one of the main objectives of warming up. Seitz and Haff (2016) proposed that resistance exercise be performed in several sets at intensities ranging from 60 to 84% of one repetition maximum (1-RM) or simply one set at > 85% of 1-RM to induce PAP. Other research (Lu, et al, 2022; Malwanage, et al., 2022; Yu & Mohamad; 2022; Jianping, 2021) also supported using heavy weights to induce PAP on athletes. However, these research are doing long-term intervention, using heavy weights to induce this effect during competition is not feasible for badminton players. Therefore, additional customization is needed for the warm-up to induce PAP.

In a research done by Maloney et al. (2014), it was discovered that a ballistic warm-up with added weight (10% of body weight) improves badminton performance via a PAP response. Chua et al. (2021) also suggest that, while dynamic warming up has numerous benefits of producing immediate improvements in speed/power performance, adding specific "preconditioning" exercises with weight of 10% body weight to a warm-up may further boost PAP and performance gains. However, in Yeung, et al. (2021)’s research, there are contradictions with the two studies, this is due to the difference in resting time. Subjects in Maloney (2014) rested for 6-8 minutes before the test while those in Yeung, et al. (2021)’s research rested for ~20 minutes, which implies that resting time might also have an impact on the effect of warm-up.

In addition, extra condition intervention may increase the risk of injury, adding extra time burden, increasing chance of fatigue, potentially leading to athlete withdrawal (Turki, et al., 2022). The ability to elicit a beneficial post warm-up PAP response without requiring heavy and specialized equipment or facilities would be a significant practical advantage for badminton players and coaches (Turki, et al., 2022; Chua et al., 2021). A well-designed warm- up routine can present a perfect opportunity to integrate a range of stimuli into the training program without imposing additional workload on the athlete (Jefferys, 2017).

#### 2.4.4 Neuromuscular warm-up (NWU)

NWU is exercises that involved dynamic movements to increase core temperature and flexibility (Fernandez-Fernandez, 2020). The training session length for NWU is relatively brief, ranging from 20 to 35 minutes. Athletic performance is likely to be improved by neuromuscular training, which will also help lower extremity biomechanics and lessen injury stresses (Stojanović, et al., 2022).

The suggested NWU protocols by Fernandez-Fernandez (2020) included: 15 repetition x 3 sets of neuromuscular-related exercises (i.e., 2–3 sets 3 6–10 repetitions of upper-body and lower-body exercises, including 1–2 kg medicine ball throw; bilateral and unilateral jumps (e.g. CMJs to 20-cm box; multilateral hops with hurdles; ankle jumps, line jumps), as well as ;10-s acceleration/deceleration/COD drills). Since the primary components of the NWU consisted of acceleration/deceleration/COD drills. Any enhancements resulting from these drills are linked to neural factors, such as the coordination of the lower limbs.

This neuromuscular warm-up effect is only investigated in tennis players but not badminton players. While both tennis and badminton both involve racket sports and specific footwork for movement. Badminton requires more lateral movement and smaller court coverage with more rapid acceleration, deceleration and COD. Therefore it is important to consider these differences with designing the routine.

From the above, it is understood that Inspiratory muscle (IM) -specific warm-up, loaded warm- up (LWU), dynamic stretching (DS) and neuromuscular warm-up (NWU) could be effective for improving badminton players' footwork performance, however, each research only focused on the effect one type of warm-up activity, while this is the first study to investigate the combined effect of these warm-up activity which were incorporated in a wholistic and structured RAMP warm-up.

## The RAMP warm-up system: concept and components

### introduction to the RAMP warm-up protocol

The RAMP (Raise, Activate, Mobilize, and Potentiate) system is a A well-designed warm-up exercise can enhance performance by increasing body temperature, enhancing blood flow, and disrupting transient connective tissue bonds, that result in quicker force development and RT, quicker muscle contraction and relaxation, reduced viscous resistance in muscles, improved oxygen delivery due to the Bohr effect and improved metabolic processes (Racinais, et al., 2017).

Additionally, by fostering the foundational athletic competencies, RAMP enables the implementation of exercises that is not only maximising performance in the following activity but also make a significant contribution to an athlete's long-term improvement (Jeffreys, 2019).

### Components of RAMP (Raise, activation, mobilisation and potentiation)

#### Raise

The goal of this phase is to raise body temperature, heart rate, respiration rate, blood flow, and joint fluid viscosity through low-intensity activities (Jeffreys, 2019). Even though most activities in general are able to achieve these goals, The RAMP system involves a more comprehensive consideration of choosing the warm-up. It also considers the needs of the following session and long term training goals (Jeffreys, 2021). For example, in badminton footwork, athlete move from point to point using chasse step, cross step, etc. therefore, this phase should focus on the technical aspects of these movement patterns.

#### Activation &Mobilization

The major goal of this phase is to activate key muscle groups and mobilize the key joints and ranges of motion used in the sport (Jeffreys, 2019). The key muscle groups used in badminton footwork are the calf muscles, hamstrings and quadriceps, gluteal, hip adductors and hip abductors. Exercise selected are mainly for activating these muscle groups and mobilizing the joints around them. Rather than concentrating on isolated specific muscles or joints, the approach is to work on movements. The dynamic nature of exercises helps to maintain the elevation effects of the first phase. Also, the movements are more specific to the selected sport.

By focusing on movements, multiple muscle groups can be activated and mobilized simultaneously (Jeffreys, 2007). Given the emphasis on movement patterns, patterns outlined by the The Functional Movement Screen (Cook, 2010) are four primary patterns that underpin effective movement: the squat, lunge, single leg stance, and brace. Including one exercise from each of these patterns can help to improve movement skills and mobilise lower-body joints (Jeffreys, 2021). The exercises can also be modified to activate torso muscles, improve shoulder mobility, and activate the posterior chain musculature. The activate and mobilise phase ensures that the desired range of motion is achieved for the upcoming badminton session.

#### Potentiation

Even following meticulously designed and skilfully executed RAM phases, the body is still not yet prepared for peak performance, particularly in scenarios demanding maximal exertion (Jeffreys ,2021). Therefore, the last phase, “potentiation” is needed. The primary objective of this phase is to raise the exercise intensity to a level where athletes can perform their training or match activities at their maximum capacity. A series of activities are employed to enable the athlete to reach peak performance when the workout or competition commences (Jeffreys, 2019).

Another goal is to capitalize on the post-activation potentiation (PAP) effect to enhance performance. Utilizing PAP research offers a pathway to improve the overall effectiveness of the warm-up, particularly in sports that demand high force and power outputs. By harnessing the benefits of post-activation potentiation, athletes can potentially boost their performance levels during the subsequent activities.

In addition, "potentiation" refers to actions that increase effectiveness, and in the context of the warm-up, it entails choosing actions that will increase the effectiveness of the subsequent performance. During this phase, the warm-up gradually transitions towards the actual sport performance or workout, involving sport-specific activities of increasing intensity. Therefore, Incorporating high-intensity dynamic exercises in this phase can promote improved subsequent performance (Opplert & Babault, 2018).

For example, according to Maloney et al. (2014a), it was found that incorporating additional load during ballistic activities, such as jumps and changes of direction, could lead to a potential post-activation performance enhancement response. The typical method of achieving this is by performing exercises while wearing a weighted vest.

It is important to note that, the potentiation phase must prepare the client for the main aspects of the main session, particularly when high-intensity activities like badminton footwork will be performed. Integrated planning is essential for a smooth transition from warm-up to main session. This preparation can be approached from a physiological, biomechanical, and skill standpoint, all of which contribute to determining the best sequence of exercises (Jeffreys, 2021).

## Summary of Literature review

Badminton footwork is critical for precise movements and accurate shot placement. It entails quick movements in six directions on the court that require agility, quick reactions, and anticipation. However, our understanding of optimising badminton footwork remains incomplete, with significant knowledge gaps to fill. The study will contribute to a better understanding of how agility and reaction time, in particular, affect badminton players' footwork by focusing on the sport's unique demands. . There is a knowledge gap regarding effective and specific strategies for comprehensively and systematically addressing these factors in the context of badminton footwork.

Assessing crucial factors in badminton footwork demands special attention, as these aspects can be significantly influenced by a well-structured warm-up routine. RT emerges as a key parameter to differentiate between agility and COD tests, heavily reliant on cognitive decision-making influenced by visual cues. BlazePodTM, an innovative reaction light device, emerges as a solution. Using interactive lights and sensors, BlazePodTM creates a dynamic testing environment. This technology tracks RT, speed, and accuracy during agility exercises, offering valuable data for performance analysis and personalized training programs.

The RAMP (Raise, Activate, Mobilise, Potentiate) warm-up system provides a structured approach. While it provides a comprehensive framework, there are knowledge gaps in customising the RAMP system for individual athletes, particularly badminton players. There was no specific warm-up protocols for badminton players and

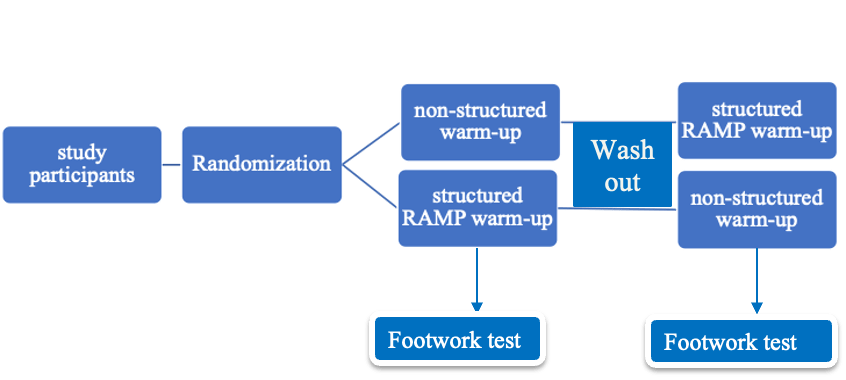
the study's exploration of the RAMP warm-up system presents an opportunity to adapt this system specifically for badminton players. By identifying the phases that align with badminton's demands, the study could propose modifications to the RAMP system, potentially leading to a novel warm-up approach tailored to the sport. This could change how coaches and players approach warm-up routines.

In conclusion, while advances have been made in understanding badminton footwork and effective warm-up protocols, gaps in knowledge persist, particularly in the context of badminton players. Bridging these gaps is critical for unlocking the full potential of badminton footwork performance.

# METHODOLOGY

## Study Design

The study protocol was examined and accepted by University Malaya's ethical committee (Reference number: UM.TNC2/UMREC\_2732) (APPENDIX D). All subjects completed a written informed consent statement before the study began, and participation was completely voluntary. This study was done with a randomised crossover design (Figure 3.1). Subjects were randomly assigned to either perform structured RAMP warm-up or unstructured warm-up first, then followed by the other warm-up. Half of the subjects began with structured warm-up then unstructured with a one-week washout period in between, the other half completed the experiment in the opposite order. Following the implementation of each warm-up, participants' performance were evaluated using a footwork test with Blazepod. The setup of footwork test was suggested by Chin, et al (1999) retested and validated by Kusuma (2015), Loureiro & de Freitas (2016) and Fernandez-Fernandez, et al. (2022).



**Figure 3.1 Study design**

## Participants

G\*Power (Figure 3.2) was performed to determine the minimum number of necessary participants for the study. "T-test" was selected in the test family and "Means: Difference between two dependent means (matched pair) was selected under the statistical test. "A priori" was chosen as the type of power analysis. It is a one tail test and the effect size was adjusted with an a-level of 0.05, a power value of 0.95 and an effect size of 0.89. therefore, at least 16 subjects are needed in this study.

Graphical user interface, application

Description automatically generated

**Figure 3.2 G\*Power results**

### Participant recruitment

Initial identification: to search for badminton players with state level or above and having regular training, Student PI will visit training venues and participants will be recruited through various badminton clubs and university badminton teams. Once potential participants have been identified, they will be screened according to their skill level, age range and physical conditions. After screening, participants will be contact directly by the student PI to provide more information about the research. Informed consent will be obtained and necessary details about the research will be provided, such as schedule, location, and any requirements they need to fulfil.

### Inclusion and exclusion criteria

18 badminton players were recruited, they were 18-35 years old, without injuries who should be at least state level and are actively participating in regular badminton training for 3-4 days a week. And they should have no experience in planning for warm-up. Participants also need to be able to understand English. Participants with injury were excluded.

## Materials and instrumentation

To perform the structured warm-up protocol, for each player, 1 weighted vest (with adjustable weight), 1 short resistance band, 1 airflow restrictive device were used. While for the footwork test, measuring tape, a BlazePod reactive agility assessment device (Figure 3.3) and the mobile app (Table 3.1) connected to it were used.

BlazePods are small, wireless, touch-sensitive LED pods that can be placed on various surfaces. The BlazePod system is frequently used for athletic training, fitness routines, and rehabilitation programmes. It provides a variety of customizable exercises and drills that test athletes' reaction time, coordination, speed, agility, and decision-making skills. The ability of BlazePod to collect real-time data and track performance provides valuable insights into athletes' progress and areas for improvement.



**Figure 3.3 Blazepod**

Note: BlazePod, UK BLAZEPOD STANDARD KIT, retrieved from: https://blazepoduk.com/cdn/shop/products/019\_2000x\_3b65da8e-d137-4a56-b2e0-444a27410bb8\_862x.jpg?v=1599477010

**Table 3.1 Blazepodz app instructions**

|  |  |  |  |
| --- | --- | --- | --- |
| Steps | Illustration | Steps | Illustration |
| 1. Tap the pod icon on top right corner to ensure all pods are connected | A screenshot of a cellphone  Description automatically generated A screenshot of a device  Description automatically generated | 4. then customize colors, lights out and light delay time to “blue”, “hit” and “none” respectively | A screenshot of a phone  Description automatically generated |
| 2. Then choose “create and save” on home page and the choose “Random” for light logic | A screenshot of a cellphone  Description automatically generated Screens screenshot of a phone  Description automatically generated | 5. lastly, finalize the settings with 1 minute duration and 1 cycle that press “start now” | A screenshot of a phone  Description automatically generated |
| 3. define general setup with “1 station”, “6 pods” and “1 player” | A screenshot of a phone  Description automatically generated |  |  |

## Procedures and Measurements

### Pre-test screening

Before the participants took part in the testing, they given full informed consent (Appendix A). A self-guided questionnaire, 2023 PAR-Q (Appendix B), was used to determine whether participants were healthy enough to participate in the study.

### Test procedure

The tests were carried out at the athletes' practice sites before their training sessions. Care was taken to clean and dry the floor where the tests were conducted to prevent any accidental slips. The tests were performed using the sports shoes typically used during practice sessions. The participants were instructed to refrain from strenuous exercise 24 hours before measurements and consume only caffeine-free beverages 4 hours before measurements.

Before testing, 1 familiarization session will be conducted for participants to familiarize with the structured RAMP warm-up and testing with BlazePod. using a crossover design, participants were assigned to non-structured and structured RAMP warm-up randomly. 9 participants assigned to non-structured warm-up first completed the warm-up then followed by structured RAMP warm-up in the next session. 1 week washout period was given between the 2 sessions. The remaining 9 participants completed the structured RAMP warm-up first followed by 1 week wash out then completed unstructured warm-up in the next session.

The warm-up procedures are described in detail in table 3.2 & 3.3. After warm-up, subjects will be given 5 minutes rest and performed a one minute footwork test based on the set-up developed by Chin, et al. (1995) (Figure3.5), the maximum number of rallies and RT achieved in 1 minute is recorded by BlazePod.. The maximum number of rallies and RT were then recorded for statistical analysis.

**Diagram, engineering drawing, schematic

Description automatically generated**

**Figure 3.4 Badminton footwork test set-up**

Note: Footwork test set-up developed by Chin, M. K., Wong, A. S., So, R. C., Siu, O. T., Steininger, K., & Lo, D. T. (1995). Sport specific fitness testing of elite badminton players. British journal of sports medicine, 29(3), 153-157.

During the test, the pods are placed on corresponding spots with the measurement of measuring tape. Then the pods were connected with the BlazePod app, after connecting the pods with the mobile app, the light logic of the pods should be set as ‘Random’, then to create the set up for footwork test, the number of “stations”, “pods” and “participants” should be set to 1, 6 and 1 respectively. After all the settings are done, the test can proceed, and the results will be recorded (table 3.1).

As soon as the corresponding light is lit, the subjects will run towards the light from the central location (point X, shown in figure 5), when the subject returns to point X from the pod, it is considered as one rally. when the forecourt and midcourt light flashes, the subjects need to execute a front and side lunge. For the rear court flashes, subjects need to turn towards the rear corner than perform front lunge like receiving a passive lobe shot. Since subjects are always facing forward, they cannot see the pods behind, instructor is needed to help giving verbal instructions to subjects if they needed to move to the rear court.

Each participant took the test once, and the results were collected for further analysis along with the total number of hits. Between each trial, there was a one-minute rest period. Each participant took the test at a moderate pace to get accustomed to the task before the first valid trial. The trial was stopped and repeated if the participant made any mistakes (such as running in the wrong direction and touching the incorrect target).

## Proposed warm-up routine

**Table 3.2 Unstructured warm-up protocol**

|  |  |  |
| --- | --- | --- |
| Exercise | Targeted Muscles/joints | volume |
| Jogging | Whole body | 1km |
| Simple stretching of own choice | Whole body | 15 minutes |

In the unstructured warm-up protocol, subjects were asked to do a general warm-up of 1km slow jogging and any stretching that they usually have been doing before any badminton session.

**Table 3.3 Structured warm-up protocol**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RAMP protocol | Physical component | Type of exercise | Targeted Muscles/joints | Time | Movement [volume] | Rest time (s) |
|  | Cardiovascular activity | Locomotor exercise  (linear) | Lower body | 5 min | Jog [25m x 2 sets] | 30 |
| Lower body | back pedal [25m x 2 sets] |
| Locomotor exercise  (lateral) | Lower body | Carioca [25m x 2 sets] |
| Lower body | Lateral shuffle [25mx 2 sets] |
| Respiratory system | IM-specific warm-up | Inspiratory muscles | 30-breaths x 2 sets (pressure threshold equivalent to 40% maximum inspiratory mouth pressure​) | 30 |
| Dynamic mobility | Dynamic stretch | Full body | 5 min | Inch-worm to downward dog [5 reps] | 30 |
| Full body | Low lunge and twist [2s x 3 each side] |
| Activation | Muscle activation and strengthening exercise | Gluteus Medius, Tensor Fascia Latae, Gluteus Maximus, leg abductors | 5 min | Monster walks [15 steps x 2] | 60 |
|  | Posterior chain muscle: hamstring, glutes, lower back, calf | Single leg deadlift with knee drive  [5 reps each side] |
|  | Force production | Ballistic exercise | quadriceps, gastrocnemius, soleus, hamstrings, gluteus maximum, abductors, adductors, core | 5 min | Box drop jump [8 reps] | 60 |
| Loaded warm-up drills  (10% body weight) | Gluteus maximus, quadriceps femoris, Gastrocnemius | 5 min | Bilateral countermovement jumps [8 reps] | 60 |
| Gluteus maximus, quadriceps femoris, Gastrocnemius, hamstrings, hip flexors, spinae erectors | Alternating split squat jumps  [4 reps x 1 each leg] | 60 |
|  | SAQ | Footwork | Whole body | 5 min | Shadowing drills [15 reps × 2 circuits] | 60 |

Apart from the activity suggested by literature from table 2.4, other exercises are included to complete the whole RAMP protocol.

### Instructions for each warm-up activity

**Table 3.4 Instructions for each warm-up activity**

| Movement | Instruction | Pictures | |
| --- | --- | --- | --- |
| Jogging | 1. Start with relaxed and slow jog. 2. Maintain an upright posture with the shoulders relaxed and the chest lifted while looking forward. 3. Swing arms naturally and keep them at 90° | Figure 3.5.1 Jogging  A group of people playing badminton  Description automatically generated | |
| Back Pedal | 1. Start with the back facing the direction of travel. 2. Maintain an upright posture with the shoulders relaxed and chest lifted. 3. Begin by taking a single step backward then shift the weight slightly onto the ball of the moving foot. This helps maintaining balance and stability. 4. Alternate between left and right foot, swing arms naturally and keep them slightly bent keep steps in controlled speed and rhythm. | Figure 3.6 Back Pedal  People playing badminton in a gym  Description automatically generated | |
| Carioca | 1. Start with facing the left side with right shoulder towards the direction of travel. 2. To begin moving to the right, step the right foot behind the left foot, crossing the left leg. while crossing the left arm across the body to the right. 3. Then, uncross the legs and step the left foot out to the side, swinging the right arm out to the side and bringing the left arm back to the side. 4. To continue, cross the right foot over the left foot in front of the left leg. Bring the left arm across the body at the same time. 5. Uncross the legs and step the left foot out to the side again. Swing the right arm out to the side and then bring the left arm back in. 6. Repeat the Pattern while keeping a rhythmic movement. | Figure 3.7 Carioca 1  A group of people playing tennis  Description automatically generated  Figure 3.8 Carioca 2  A group of people playing badminton  Description automatically generated  Figure 3.9 Carioca 3  A group of people playing badminton  Description automatically generated  Figure 3.10 Carioca 4  A group of people playing badminton  Description automatically generated | |
| Lateral Shuffle | 1. Start with facing the side with one shoulder towards the direction of travel. 2. Stand with feet shoulder-width apart and knees slightly bent. Maintain a raised chest and a tight core. 3. Maintaining an upright, relaxed posture and a forward gaze. 4. Begin by taking a right-footed step to the side. Bring the left foot up to meet the right foot as quickly as possible. 5. Repeat movement, continue to shuffle laterally, alternating between right and left foot. Maintain a quick and controlled gait. | Figure 3.11 Lateral Shuffle 1  A group of people standing on a court  Description automatically generated  Figure 3.12 Lateral Shuffle 2  A group of people playing badminton  Description automatically generated  Figure 3.13 Lateral Shuffle 3  A group of people playing badminton  Description automatically generated | |
| IM-specific warm-up | 1. Make sure the inspiratory device is properly set and calibrated to provide resistance at a pressure threshold equal to 40% of the maximum inspiratory mouth pressure. For proper setup, follow the manufacturer's instructions. 2. Begin the warm-up in a comfortable and upright position, maintaining good posture to allow for optimal lung expansion. 3. Insert the inspiratory device's mouthpiece into the mouth.Firmly grip the device. Breathe in using only the inspiratory muscles through the device. 4. Slowly and deeply inhale through the device. Exhale naturally rather than using the device. 5. Feel the resistance while inhaling through the device. 6. Maintain steady, controlled inhalation and gradually overcome the resistance. | Figure 3.14 IM-specific warm-up: exhalation  A person sitting on a bench  Description automatically generated | Figure 3.15IM-specific warm-up: inhalation  A person sitting on a bench  Description automatically generated |
| Inch worm to downward dog | 1. Stand tall, with feet hip-width apart. Maintain a slight bend in the knees and a tight core. 2. Begin by hinging at the hips and bending forward. While reaching for the floor, allow the hands to touch the ground in front. 3. Then start walking the hands forward, one at a time, on the ground, while keeping the legs relatively straight. Move hands away from the feet and lower the upper body to the floor gradually. 4. Continue to walk hands forward until the plank position. A straight line should be formed from head to toes. 5. Maintain stability by engaging the core muscles. 6. Lift the hips up and back from the plank position, forming an inverted V with the body. Hands and feet should be shoulder-width apart and hip-width apart respectively. 7. Press the palms into the ground and actively push the hips up towards the ceiling into a Downward Dog Pose. Keep the heels reaching for the floor, but don't let them touch. 8. Allow the neck to relax and head to hang comfortably between the arms. feel the stretch in the hamstrings, calves, shoulders, and back. 9. Return to the plank position by walking hands back towards the feet from the downward dog pose. 10. Slowly walk the hands back towards the feet, reversing the inchworm movement. 11. Begin rolling the spine up, maintain a relaxed head and neck while engaging the core. 12. Stand tall with the feet hip-width apart once fully upright. Maintain good posture by rolling the shoulders back and down. | Figure 3.16 Inch worm to downward dog 1  A person in a gym  Description automatically generated  Figure 3.17Inch worm to downward dog 3  Two people doing push ups in a gym  Description automatically generated | Figure 3.18Inch worm to downward dog 2  A child doing push ups on a blue floor  Description automatically generated  Figure 3.19Inch worm to downward dog 4  A group of people in a gym  Description automatically generated |
| Low lunge and twist into overhead reach | 1. Keep the feet together and stand up straight. Take a step back, extending the right foot straight behind. Create a lunge position by lowering the right knee to the ground. 2. Keep the left knee directly above the left ankle in a low lunge. Gently press the hips forward to feel a stretch in right hip flexor. 3. Put right hand on the ground right below the shoulder. Try to reach the left ankle with left elbow. 4. Exhale while twisting the torso to the left. Raise the left arm towards the ceiling at the same time for an overhead reach. 5. Extend both arms fully to form a straight line from right hand to left hand. Look up at the left hand, allowing the neck to twist with it. 6. Maintain the twist and overhead reach for a few deep breaths, feeling the stretch along the spine and chest. 7. Back to the Centre by lowering the right arm after releasing the twist. Return the hands next to the foot 8. Repeat with the other side. | Figure 3.20 Low lunge and twist into overhead reach 1  A group of people in a gym  Description automatically generated  Figure 3.21Low lunge and twist into overhead reach 3  A group of people in a gym  Description automatically generated | Figure 3.22Low lunge and twist into overhead reach 2  A group of people doing push ups in a gym  Description automatically generated |
| Monster walks | 1. Stand tall, the feet hip-width apart. Maintain good posture by engaging the core muscles. 2. A resistance band should be placed just above the knees. The band should be snug enough to provide resistance but not so tight that it is uncomfortable. 3. Maintain a comfortable and athletic stance by bending the knees slightly. 4. With the right foot, take a step to the side. The step should be big enough to make the resistance band tense. 5. Bring the left foot in to meet the right foot while stepping the right foot out. Maintain band tension throughout the movement. 6. Step to the side with each foot alternately, keeping a steady and controlled pace. | Figure 3.23 Monster walks 1  A person standing in a room  Description automatically generated  Figure 3.24 Monster walks 3  A person squatting on a bench  Description automatically generated | Figure 3.25 Monster walks 2  A person doing a jump rope  Description automatically generated |
| Single leg deadlift with knee drive | 1. Keep the feet together and stand up straight. Shift the weight to the left foot, lifting the right foot slightly off the ground. 2. Hinge forward at the hips while straightening the right leg behind. The torso and right leg should form a straight line from head to heel, parallel to the ground. 3. For balance, keep the core engaged and the left knee slightly bent. To counterbalance, let the arms hang in front or extend out to the sides. 4. Lift the right knee in a controlled motion towards the chest when coming up from the hinge. Aim to bring the knee to or slightly above hip level. 5. Squeeze the left glute at the top of the movement to fully extend the hip and bring the torso upright. 6. Return the right leg to its starting position while simultaneously hinging forward at the hips. 7. Repeat with the other side | Figure 3.26 Single leg deadlift with knee drive 1    Figure 3.27 Single leg deadlift with knee drive 2    Figure 3.28 Single leg deadlift with knee drive 3    Figure 3.29 Single leg deadlift with knee drive 4 | |
| Box drop jump | 1. Pick a stable box or platform at a comfortable height. Make sure the ground is stable and non-slip. 2. Stand with the feet hip-width apart on the box or platform. Keep the shoulders relaxed and the core engaged to maintain good posture. 3. Step off the box one foot at a time to begin jumping down. Concentrate on taking a controlled step down and landing with both feet on the ground at the same time. 4. Bend the knees as you land to absorb the impact. Aim to land with the weight in the center of the body and the body stable. Ensure a controlled, quiet landing. | Figure 3.30 Box drop jump 1    Figure 3.31Box drop jump 2    Figure 3.32 Box drop jump 3 | |
| Loaded bilateral countermovement jump | 1. Adjust weight of weighted vest to 10% of body weight, wear the weighted vest. Put the feet shoulder-width apart and stand straight up. Maintain relaxed arms by the sides. 2. Start by bending the knees slightly into half squat position, then produce a countermovement. This requires a swift, deliberate downward motion. 3. Explosively jump upward while extending the hips and knees from the bent-knee position. To generate upward momentum, swing the arms. 4. Land gently with the knees bent to lessen the force of the landing while descending. 5. Immediately after landing, quickly flex the knees and hips to cushion the impact before rebounding into the following jump. 6. Perform a series of continuous jumps while maintaining the countermovement pattern. | Figure 3.33 Loaded bilateral countermovement jump 1  A person in a white uniform squatting on a blue court  Description automatically generated  Figure 3.34 Loaded bilateral countermovement jump 2  A person in a sports uniform squatting on a court  Description automatically generated | Figure 3.35Loaded bilateral countermovement jump 3  A person in a vest and shorts  Description automatically generated |
| Loaded alternating split squat jump | 1. Adjust weight of weighted vest to 10% of body weight, wear the weighted vest. Put the feet shoulder-width apart and stand straight up. Maintain relaxed arms by the sides. 2. Step backwards with the right foot while bending the body into a lunge position. The right knee should be just above the floor, and the left knee should be bent at about 90°. 3. To jump off the ground, powerfully push through the left foot. Change the position of the legs in the air as you jump by bringing the right foot forward and the left foot back. 4. Lunge into position by softly landing with the right foot behind and the left foot in front. Maintain a bent knee position to lessen impact. 5. Immediately after landing, jump again while switching the leg positions once more so that the right foot is in front and the left foot is at the back. | Figure 3.36 Loaded alternating split squat jump 1  A person in a sports uniform running on a court  Description automatically generated  Figure 3.37Loaded alternating split squat jump 2  A person jumping in a gym  Description automatically generated | Figure 3.38Loaded alternating split squat jump 3  *A child running on a court  Description automatically generated* |
| Shadowing drills | 1. Knees slightly bent, racket in hand, stay in the middle of the court, this is the ready position. 2. Ask a partner to point in the desired location (front court left and right, mid court, and rear court). 3. Move to the designated location as soon as the call is made, simulating your response to the shot. 4. Return to the ready position in the middle of the court after each movement. 5. carry out the exercise in a random order. Each call should be handled quickly and effectively. | Figure 3.39 Shadowing drills 1  A group of people playing badminton  Description automatically generated  Figure 3.40 Shadowing drills 2  A group of people playing volleyball  Description automatically generated  Figure 3.41 Shadowing drills 3 | Figure 3.42 Shadowing drills 4  A group of people playing volleyball  Description automatically generated  Figure 3.43 Shadowing drills 5    Figure 3.44 Shadowing drills 6 |

# RESULTS

## Results

A total of 23 non-injured badminton athletes participated in the study, and 18 participants were deemed eligible; 5 participants were excluded since their results were outliers. The characteristics of participants were presented in table 4.1.

The 18 eligible participants, included n = 9 males and n = 9 females, aging from 18-34 years old (M=22.8, SD=4.40), average height of 1.67±0.05m, average weight of 63.89±4.80kg average BMI of 22.91±1.53 and spent 11.5 ± 2.23 hours per week on training.

**Table 4.1 Characteristics of participants**

|  |  |
| --- | --- |
| Age, years | 22.80±4.40 |
| Sex, n | Male = 9 & female = 9 |
| Height, m | 1.67±0.05 |
| Weight, kg | 63.89±4.80 |
| Body mass index, kg/m^2 | 22.91±1.53 |
| time spent on training, hours per week | 11.5±2.23 |

The mean for number of hits for unstructured and warm-up were 23.75 ±1.25 and 24.40 ±1.60 respectively, there was an increase in 2.74%.

The mean for RT for unstructured and structured warm-up were 2358.4±146.30ms and 2321.4±157.00ms respectively, there was a decrease in 1.57% (table 4.2).

**Table 4.2**  **Mean, SD, UL and UL, t-test of footwork performance test results**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | No. of hits | | | | | Reaction time (ms) | | | | |
| Warm-up | M | SD | | UL | LL | t-test | | M | SD | UL | LL | t-test |
| Unstructured | 23.75 | 1.25 | | 25.00 | 22.50 | | -0.301\* | 2358.40 | 146.30 | 2504.70 | 2212.10 | 2.424\* |
| Structured | 24.40 | 1.60 | | 26.00 | 22.80 | | 2321.4 | 157.00 | 2478.40 | 2164.40 |

\* p<0.05

Paired t-test was applied to compare the effects of unstructured and structured warm-up. Figure 4.2 shows the results of footwork performance test regarding the number of hits. There was an increase in number of hits when comparing the results from structured to unstructured warm-up. There was significance difference between structured and non-structured warm-up (t=-0.301, df=17, p=0.001). It means that the structured warm-up protocol is effective to increase agility.

**Figure 4.1 Results of footwork performance test (Number of hits)**

Figure 4.2 shows the results of footwork performance test regarding RT.

There was an decrease in RT when comparing the results from structured to unstructured warm-up. there is significance difference between structured and non-structured warm-up (t=2.424, df=17, p=0.025). It means that the structured warm-up protocol is effective to increase reaction time.

**Figure 4.2 Results of footwork performance test (RT)**

# DISCUSSION

The aim of this study was to examine to effect of a structured warm-up on badminton footwork performance in comparison with unstructured warm-up. The results reflects that the structured warm-up yielded significant effect on footwork performance while not for unstructured warm-up. The order of warm-up does not affect the performance of footwork. In other words, there are no systematic differences in the outcomes based on the order in which the treatments are administered.

From the results, the increase in number of hits and decrease in RT indicated that there was improvement in footwork performance. The improvement in RT and number of hits further consolidated that the structured RAMP warm-up appears to be better in preparing for the badminton footwork physically and mentally. The results also aligned with previous research that RAMP warm-up can positively affect sports performance (Jeffreys, 2006; Jeffreys, 2017; Jeffereys, 2021).

## Impact of structured RAMP warm-up on footwork performance

The observed increase in the number of hits after implementing the structured warm-up protocol demonstrates a significant improvement in agility. The statistical data revealed a significant increase in the mean number of hits of 2.74% when participants switched from the unstructured to the structured warm-up. This improvement demonstrates the positive impact that a targeted warm-up routine can have on badminton footwork proficiency. Given the high tempo of badminton match play, with a shot frequency of approximately 0.9-1.3 shots per second (Phomsoupha & Laffaye, 2015), having a faster and better prepared physical and mental start at the beginning of the match (within the first 5-10 minutes) would be beneficial for players to react swiftly to shots during rallies, whether in defence or attack (Chua, et al., 2021).

The reduction in RT, an important indicator of quick decision-making indicates a significant improvement in footwork performance due to the structured warm-up protocol. The statistical analysis revealed a significant reduction of 1.57% in mean RT when participants switched from the unstructured warm-up to the structured warm-up. This decrease emphasises the effectiveness of a well-designed warm-up routine in positively influencing participants' cognitive and physical preparedness.

In badminton, faster RTs can give athletes a competitive edge by allowing them to react to opponents' shots faster and gain a tactical advantage. Maintaining elite performance in badminton requires a fast RT to cope with the game's high speed (Loureiro and Freitas, 2012). Additionally, the opponent's unpredictable actions and the utilization of feint strokes at an elite level underscore the significance of inhibitory control for achieving top-tier performance (Van de Water, 2017).

It could be seen clearly that having a structured warm-up protocol does help improve badminton footwork performance, and this was the first study to provide a wholistic structured warm-up protocol for badminton players to improve their footwork performance. The effects of particular interventions have been extensively studied, there remains a lack of conclusive evidence regarding the ideal arrangement of a warm-up routine and how strategically organizing exercises can maximize the advantages of one activity to enhance performance in the following activity (Jeffreys, 2017). Previous study showing certain activity causes positive changes in footwork performance aligns with our study results (Chua, et al., 2021; Lin, et al., 2007; Yeung et al., 2021; Maloney, et al., 2014; Lin, Lee & Chang, 2020) but no research have suggested a structured RAMP warm-up specifically for badminton athletes.

According to Gamlath, et al. (2021), Warm-up programmes have traditionally focused on energy systems and physiological processes, while the neurological aspects of the warm-up are frequently overlooked. However, neurological aspects plays a very important role in agility and badminton gameplay due to its unpredictable nature, therefore, neurological effect on badminton footwork had to be considered as well (Gamlath, et al., 2021),

During warm-up, elevating temperature impacts the muscle environment by promoting local vasodilation and increasing both nerve and sarcolemma action potentials, thus complete activation and force production (Racinais, et al., 2017), therefore improving the number of hits.

Also, since one of the goals of RAMP warm-up is to elevate neuromuscular activity, which, in turn, can enhance performance in subsequent exercises (Jeffreys, 2007). This is believed to result in greater activation of fast-twitch muscle fibers, ‘pre-condition’ the muscles and induce PAP (Racinais, et al., 2017), which activate motor units, stimulate sensory receptors, and potentiate muscle function, athletes experience improved neural communication, coordination, and responsiveness, thus faster RT contributing to improved performance (Nygaard, 2019; Jeffreys, 2021).

## Well-planned and sport-specific nature of structured RAMP warm-up

According to Jeffreys (2017), effectively planned warm-ups must consider skill development and other key goals of the athlete's programme in addition to purely physiological preparation. This intervention is efficient in a way that, with well-planned and structured warm-up protocol, there is a main and clear objective is to improve badminton footwork performance, which contributes directly to the goal of main session. This provide more seamless and consistent transition between warm-up and the main session (Jeffreys, 2017). This also proves that The RAMP warm-up system was effective to enhance immediate performance while also ensuring that each activity within the warm-up sequence optimally prepares for the subsequent activities in a time and energy-efficient manner (Jeffreys, 2007; Jeffreys, 2017).

The structured RAMP warm-up protocol follows a systematic method of gradually intensifying and adding complexity to warm-up exercises. This approach stimulates both the physiological and neuromuscular systems, effectively preparing them for the specific movements and demands of the sport (Racinais, Cocking, & Périard., 2017). The exercises included in the structured warm-up closely mimic the demands of badminton footwork, involving lateral movements, lunges, and quick changes in direction (Hung, 2020), which also activates the participants' muscles and joints for the movements required during the game, resulting in improved agility.

The structured RAMP warm-up protocol used in this study was specifically designed for badminton players. The first phase, *Raise*, which included low-intensity cardiovascular exercises, was designed to raise participants' heart rates and increase blood flow to working muscles (Jeffreys, 2021). This increased the players' body temperature and metabolic rate, resulting in better muscle function and flexibility (Racinais, Cocking, & Périard, 2017). The following activation exercises aim to activate lower limb muscles with the effect of PAP.

In the *Activation and mobilization* phase, dynamic stretching exercises targeted the lower limbs hip mobility, focusing on specific muscles and joint ranges of motion relevant to badminton footwork (Jeffreys, 2021). This improved flexibility and reduced the risk of injury during dynamic movements on the court. The United States Army Physical Fitness School discovered that dynamic warm-ups help to increase body temperature and heart rate, joint and muscle pliability, and nerve and muscle responsiveness in preparation for physical readiness to training activities (Gamlath, et al., 2021).

Lastly, in the *Potentiation* phase, it has the goal of increasing activity to maximum intensity and potentiating PAP, using done by adding resistance (Jeffreys, 2021). Aandahl et al. (2018) reported that when additional resistance was provided during warm-ups, taekwando performance was improved by 3.3% and rectus femoris EMG activity increased. According to another study, a loaded warm-up may have influenced potential factors influencing the extent of the PAP effect, such as increases in muscle temperature and water, as well as improvements in muscle activation/neural drive and motivation/arousal levels. (Chua et al., 2021).

In addition, a research done by Chua et al. (2021) demonstrated that a weighted warm-up routine resulted in significantly faster CODS, thus better footwork performance. It is hypothesised that the improved performances could be attributed to an increase in motor unit recruitment, a boost in motor unit synchronisation, and a decrease in pre-synaptic inhibition. Similar mechanisms could account for the quicker CODS found in badminton (Chua, et al., 2021). The activities chosen in this warm-up protocol were able to help improving agility which use the adaptation of stretch-shortening cycles through the neuromuscular system to help increase leg muscle power and thus improve agility (Irawan, 2017; Werfelli, et al., 2021).

This phase provides one of the most powerful tools for athletic development, in addition to optimally preparing the athlete for the upcoming session, also provides the opportunity to engage in long term athletic development, particularly in terms of the development of speed, agility, and power-based activities (Jeffreys, 2019).

Lastly, the warm-up protocol was concluded with sport-specific footwork drills that closely resembled the movements performed during badminton matches.

## Practical implications for coaches and athletes

The findings of the study could also serve as the basis for coaches and athletes looking to acutely improve badminton performance through specialised warm-up routines. Since footwork as one of the major performance indicator, many coaches have been training athletes with long-term intervention. The findings of this study provide evidence to affect footwork acutely and a framework for developing warm-up routines that are tailored to the specific demands of badminton, ultimately contributing to improved footwork proficiency and overall athletic performance. The study can provide insights into targeted training strategies by conducting a thorough investigation of agility and reaction time in badminton. The study can shape training approaches that are tailored to the sport's unique requirements by specifically addressing badminton footwork. This could lead to novel footwork techniques and drills that effectively improve players' ability to anticipate and respond to dynamic gameplay.

## Future research

Even though different stretching and warming-up exercises are frequently advised before to physical activity, little study has been done to ascertain the effects of these exercises on badminton athletic performance. The variety of research designs makes data comparison difficult (e.g., protocols, outcomes targeted, number of participants, and athlete skill level, etc.). Despite research demonstrating the effectiveness of various warm-up activities on badminton footwork performance, no research has suggested a comprehensive protocol and warm-up sequence to guide coaches and players throughout their entire warm-up session.

This study is the first to investigate how warm-up strategies affect badminton footwork performance. The lack of prior research on badminton footwork provides an opportunity to set a standard for future research endeavours.

The findings and methodologies of this study can be used as a starting point for future researchers interested in footwork performance, warm-up strategies, and related measurements in badminton. This study, the first of its kind, contributes to a more complete understanding of the multifaceted nature of badminton performance. It adds to existing knowledge by emphasising the intricate relationship between warm-up strategies, footwork execution, and overall gameplay efficacy.

## Limitation

The study lacked control over individual differences among participants, such as varying levels of strength, badminton ability/training experience, and the specific discipline they belonged to (singles, women/men doubles, or mixed doubles) and individuals may respond to warm-up differently. Future research should consider these differences as well. This research only focused on lower body performance, however, upper body movement also plays a very crucial role in badminton gameplay performance. Ignoring the upper body's role in shot and racket control can limit the study's applicability to the holistic nature of badminton performance. One suggestion is to combine the structured RAMP warm-up with elements of upper body warm-up. This hybrid approach retains the structured protocol's effectiveness while addressing the limitation of overlooking upper body engagement. It offers a balanced warm-up that corresponds to the multifaceted demands of badminton. The current study's sample size may limit its generalizability to a broader range of badminton players. A larger sample size would increase the study's statistical power and allow for a more comprehensive understanding of how different demographic and skill-related factors interact with the effects of the structured warm-up. Furthermore, RAMP may not be the only way to structure warm-up for athletes, there could be other ways to improve badminton footwork performance as well.

# CONCLUSION

To conclude, the results show that the structured warm-up significantly improved footwork, the structured RAMP warm-up proved to be effective by improving agility as evidenced by more hits and faster RTs. It is also observed that even though there might not be increase in number of hits, the RT of players also decreased slightly. There is a slight improvement in RT but not enough to assist the athlete to improve one rally and there was not much improvement in acceleration and deceleration, which caused no improvement in number of hits.

The study emphasised the value of specifically structured warm-up routines to enhance footwork proficiency in line with badminton gameplay characteristics. Contrast to unstructured and general warm-up, the structured RAMP warm-up not only physically prepared participants but also improved cognitive and neural readiness, contributing to better agility and footwork execution. This study offers insightful information for coaches and athletes looking to improve immediate badminton footwork performance through efficient warm-up techniques.

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APPENDIX : Consent form

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APPENDIX : 2023 PARQ+

A close-up of a questionnaire

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APPENDIX : Footwork test results

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Unstrucutred | | | Structured | | |  |  |  |  |
| Subject | Age | Gender | No. of hits | | Reaction (ms) | | No. of hits | Reaction (ms) | Weight (kg) | Height (m) | BMI | Training hours per week |
| 1 | 23 | F | 23 | 2441 | | 23 | | 2451 | 60 | 1.7 | 20.76125 | 12 |
| 2 | 18 | F | 23 | 2494 | | 23 | | 2478 | 63 | 1.65 | 23.14050 | 12 |
| 3 | 24 | M | 25 | 2235 | | 25 | | 2234 | 69 | 1.75 | 22.53061 | 14 |
| 4 | 18 | F | 20 | 2733 | | 20 | | 2732 | 64 | 1.66 | 23.22543 | 8 |
| 5 | 18 | M | 24 | 2398 | | 25 | | 2274 | 66 | 1.65 | 24.24242 | 13 |
| 6 | 23 | M | 25 | 2215 | | 26 | | 2167 | 72 | 1.78 | 22.72440 | 15 |
| 7 | 20 | M | 23 | 2311 | | 25 | | 2254 | 65 | 1.66 | 23.58833 | 13 |
| 8 | 25 | M | 24 | 2256 | | 24 | | 2352 | 68 | 1.7 | 23.52941 | 14 |
| 9 | 34 | M | 25 | 2197 | | 26 | | 2179 | 70 | 1.68 | 24.80159 | 14 |
| 10 | 20 | M | 23 | 2489 | | 25 | | 2290 | 66 | 1.65 | 24.24242 | 10 |
| 11 | 25 | M | 25 | 2214 | | 25 | | 2165 | 67 | 1.66 | 24.3141 | 12 |
| 12 | 23 | F | 23 | 2446 | | 23 | | 2478 | 59 | 1.74 | 19.48738 | 12 |
| 13 | 20 | F | 23 | 2498 | | 23 | | 2477 | 58 | 1.64 | 21.56454 | 12 |
| 14 | 18 | F | 25 | 2214 | | 26 | | 2199 | 57 | 1.61 | 21.98989 | 14 |
| 15 | 19 | M | 23 | 2504 | | 23 | | 2470 | 60 | 1.66 | 21.77384 | 11 |
| 16 | 26 | F | 25 | 2214 | | 26 | | 2182 | 67 | 1.64 | 24.91077 | 8 |
| 17 | 32 | M | 25 | 2215 | | 26 | | 2189 | 66 | 1.66 | 23.95122 | 10 |
| 18 | 23 | F | 23 | 2459 | | 23 | | 2458 | 54 | 1.6 | 21.09375 | 8 |
| 19 | 22 | F | 24 | 2356 | | 26 | | 2165 | 67 | 1.64 | 24.91077 | 8 |
| 20 | 25 | F | 24 | 2279 | | 25 | | 2234 | 66 | 1.67 | 23.66524 | 9 |
| 21 | 28 | F | 22 | 2453 | | 24 | | 2232 | 63 | 1.55 | 26.22268 | 8 |

APPENDIX : UMREC approval letter

A paper with a letter

Description automatically generated