Mechanical load differences between practice and match play in badminton

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Received: 18-07-2023

Accepted: 01-04-2024

Abstract

Badminton is a demanding high-intensity intermittent sport, which has a high injury rate compared to other racket sports. The racket leg and lower back are particularly susceptible to injury due to the high mechanical loads experienced from repetitive jumping actions. The purpose of this study was to evaluate the mechanical load differences on landing between predictable practice activities and competitive match play. Nineteen national and international standard badminton players participated in this study. Participants randomly undertook a match play and multifeed trial with Vicon Blue Trident IMU sensors collecting mechanical load data from the shank of the racket leg and the lower back. All trials were digitally recorded and movements to the four corners (forecourt forehand, forecourt backhand, rear court forehand and rear court around the head) were tagged using Dartfish version 10 video analysis software. Results showed the peak mechanical load in the shank of the racket leg and lower back for forecourt and rear court movements to be significantly higher in match play trials compared to multifeed. Match play trials also presented with a greater variation in peak mechanical load. Findings suggest the mechanical load experienced in competitive match play is not simulated by predictable practice activity. Due to the high prevalence of lower back and lower extremity injuries in badminton, findings support the need for badminton practice to contain unpredictable feeding activities to prepare the body for the high mechanical loads of match play. Unpredictable feeding strategies are suggested for coaches.

Keywords: *visual search behaviour, elite, coaching, representative learning design.*

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Cite this article as:
Smith, S., Jessop, D., Grimes, P., & Baczala O. (2023). Mechanical load differences between practice and match play in badminton. *International Journal of Racket Sports Science, 5*(2), 1-8.

INTRODUCTION

Badminton played at an elite level requires significant hours of practice for demanding high-intensity intermittent competitive match play (Phomsoupha & Laffaye, 2015). Previous research states badminton injury rates per player per 1000 hours of exposure to be as high as 5.1 (Miyake et al., 2016). When compared to other racket sports, such as tennis (0.04-3 injuries per player per 1000 hours) (Pluim et al., 2006) and squash (4.78 injuries per player per 1000 hours) (Horobeanu et al., 2019), badminton can be considered as holding a relatively high injury rate. Mechanical load, which refers to the "forces experienced by specific tissues or biological structures" (Kalkhoven et al., 2021), in repetitive jumping sports such as badminton is high and accountable for much of the overload injuries suffered (Couppé et al., 2013).

Elite badminton players commonly report injuries to the lower limbs, lower back, and shoulder (Goh et al., 2013), which has both financial implications (Yung et al., 2007) as well as performance impacts through lost practice and competition participation (Wong et al., 2015). A systematic review of badminton injuries conducted by Fatahi et al. (2022) found that lower back injury was more prevalent than shoulder injury in the upper extremity with ankle (typically sprains) and knee injury being the most common in the lower extremities. The lower back, knee and ankle are subject to repetitive high force landings with significant shearing force in badminton (Hu et al., 2022), which explains the propensity for injury in those joints. A recent review of badminton injuries in elite athletes by Pardiwala et al. (2020) highlighted injuries occurred frequently in the competitive setting, which could be attributed to poor conditioning from the practice environment.

Phomsoupha and Laffaye (2020) suggest that core muscle instability can increase the risk of knee injury when forward lunging due to incorrect knee flexor muscle recruitment, with players performing greater knee flexion to combat injury. Smith et al. (2022) recently undertook the first known badminton study to evaluate the biomechanical differences between practice activities and competitive match play, finding significant differences in the forward lunge technique. For example, Smith and colleagues reported higher wrist and shoulder positions, lesser knee flexion, and decreased forward trunk lean when forward lunging during predictable practice routines compared to competitive match play, which could have a detrimental impact on injury prevention through unconditioned trunk musculature (Huang et al., 2014; Phomsoupha and Laffaye, 2020). Therefore, predictable practice activity led to biomechanical differences in forward lunge technique with the lunge being less deep compared to match play trials that could insufficiently prepare the body for the mechanical loads of match play.

To better understand the competitive demands of sport competition, and how practice can best represent those demands, practice design has attracted much recent research attention (Woods et al., 2020). Araújo et al. (2020) highlights the crucial role spatial-temporal cues play within skill acquisition and practice through the continuous interplay between possibilities and actions. Importantly, practice environments that provide activities that are representative of the perceptual information available in competition, offer athletes an enhanced ability to develop adaptive behaviours and movements to cope with the physical demands of the sport (Pinder et al., 2011). A failure to provide a representative practice environment could inadequately prepare key muscles and physiological systems through maladaptive skill acquisition and practice, which would increase the likelihood of injury.

Badminton practice approaches, that include predictable feeding routines, are commonplace globally as suggested by the Badminton World Federation (BWF) in their Coach Education Level 2 Award. Predictable badminton practice routines can be classified as holding low levels of visual search behaviour (VSB). For example, a predictable practice routine with low VSB would be shuttlecock feeding with the same action (e.g., underarm) from a static location on the court (see Smith et al., 2022) that decreases the attention and decision making required in match play (Natsuhara et al., 2020). Despite previous research finding high physiological loads decreased the efficiency of VSB and response accuracy in artificially created badminton scenarios (Alder et al., 2019), there was no identification of the physiological load differences with varying levels of VSB (i.e., differences between predictable practice and competitive match play). Also, previous badminton movement research is often limited to laboratory-based analysis (e.g., Kuntze et al., 2010; Lam et al., 2020; Nielsen et al., 2020), which is incapable of representing the real-world mechanical load experienced by players in competitive match play situations. Previous badminton research, therefore, has not been able to identify the physiological or mechanical load differences under differing VSB conditions. An understanding of the mechanical loads in different VSB badminton scenarios will better prepare coaches and players to create representative practice designs that prepare athletes for the competitive demands of badminton and decrease injury rate.

The purpose of this study was to evaluate the mechanical load differences on landing between predictable practice (low VSB) activities and competitive match play (full VSB) in key areas of the body that are susceptible to the highest injury rates in badminton. Specifically, mechanical load through the distal tibia of the racket leg and lumbar vertebrae 5 of the lower back. Mechanical load discrepancies between predictable practice and competition environments will provide a justification for practice activities to better represent the competitive environment (e.g., for practice environments to increase VSB). Practice environments predicated on predictable routines, therefore, may cause increased chances of both acute and overuse injury.

METHOD

Participants

Nineteen (16 male and 3 female) national and international standard badminton players participated in this study. Mean age was 20.6 ± 6 years, mean height was 1.74 ± 10.1 m, mean body mass was 70.3 ± 13.3 kg and mean competitive playing experience was 10.7 ± 6.8 years. Participants were representative of several ethnicities, which were White British (13), Chinese (4), British Other (2) and Pakistani British (1). Participants were recruited from clubs and training groups in the south of England, UK. All participants competed in singles events at a minimum of national tournament level.

Design & procedures

Ethical approval was gained from the University ethics board and all participants provided written informed consent. All participants randomly undertook a match play (highest VSB) and multifeed (low VSB) trial. The match play trial consisted of one game to 21 points against an evenly matched opponent based on previous head-to-head record, ranking, and competition level. To create competition similar to tournament play, the winner of the match play trial was award 30 GBP. Yonex AS30 Shuttlecocks were used across all trials.

The multifeed trial consisted of the same high level coach feeding participants 34 sets of 5 shuttlecocks from the central base position on the opposite side of the court. The coach randomly hit all shuttlecocks with a low forehand swing (see Smith et al., 2022, figure 3d) to the four corners of the court, which were forecourt forehand (FCFH), forecourt backhand (FCBH), rear court forehand (RCFH) and rear court around the head (RCATH). Participants were given 20 seconds rest between sets. Previous match analysis research (Abdullahi & Coetzee, 2017; Abian-Vicen et al., 2013; Chiminazzo et al., 2018; Gómez et al., 2021; Iizuka et al., 2020; Leong & Krasilshchikov, 2016; Torres-Luque et al., 2020; Torres-Luque et al., 2019) was averaged to provide the rally shots, rallies per set and rally rest time for the multifeed trial to accurately simulate a competitive match. Participants were given a minimum of 10 minutes recovery between trials.

Data were collected at 1600 Hz using Vicon Blue Trident IMU sensors (9.5 grams, ± 200 g), which have been reported to have very high reliability during functional sport movements (Burland et al., 2021). For each participant, one sensor was securely attached to the shank (distal medial aspect of the tibia) of the racket leg and one centrally to the lower back (lumbar vertebrae 5). An Olympus Tough TG-5 digital camera recorded all trials.

Analysis

Using digital recordings, movement (FCFH, FCBH, RCFH and RCATH) landings were tagged in each trial using Dartfish version 10 video analysis software with times exported in .csv format. Only movements that initiated from a central base position and ended in one of the four corners of the court were analysed. Data were then parsed and processed in Matlab version 9.13. Time series and tagging times were aligned using the landing impact from a vertical jump performed by each participant at the start of each trial.

From the raw data, resultant accelerations were calculated, and 1 g subtracted to remove the effect of gravity. Descriptive data (trial duration, number of movements per movement type, and number of samples above threshold acceleration values) were found for the whole trial. For each tagged event, a window in the data was created at 0.0167 s before the tagged time (to allow up to one frame in case the landing was late in the tagged frame) and until 0.5 s after the time of each event. Within that window, peak g and time to the peak following the last sample greater than 3 g were recorded. Where there was no peak greater than 3 g, no data were recorded for that sensor for that event.

Given that the majority of sensor data were low g (10 g or less), the data were considered non-parametric and therefore the choice of statistics were considered accordingly. Medians and inter-quartile ranges (IQR) were used to describe the average and spread of data whilst a Wilcoxon Signed Ranks test provided a statistical comparison between groups. In total, 24 tests were conducted and so a Bonferroni correction was applied to maintain statistical significance at $P < 0.05$. Where there were different numbers of samples between groups, a random number of samples equivalent to the samples in the shorter data set were taken.

RESULTS

Multi-feed trials were ~1.6 times longer than the match play trials and contained ~3 times as many tagged movements (Table 1). Despite this, the distribution of movements was similar for both conditions (Figure 1). Given that the multi-feed trials were both longer and contained more movements, whole trial data were considered in terms of the frequency of high g samples. Table 2 compares the frequency of samples above thresholds at intervals of 10 g up to 100 g. Clearly, the shank data observed a higher frequency of peaks than the back, and at higher g. Whilst the match-play trials were shorter than the multi-feed trials, both the median frequency of peaks at the shank over all participants, and maximum frequency of peaks by any participant, were higher at each threshold in the match-play condition. The IQR's were also larger in the match-play condition suggesting greater variation in peaks during match-play.

When considering the distribution of high g samples, Figure 2a shows a higher distribution of samples at every threshold over 30 g (for clarity, the lower threshold values at 10 and 20 g were removed from the figure: multi-feed samples > 10 g = 79%, multi-feed samples > 20g = 14%; match-play samples > 10 g = 76%, match-play samples > 20g = 15%). Whilst the peak accelerations were lower in the back sensor, a similar trend was observed with a higher frequency of peaks at all threshold levels (Table 2, figure 2b). The data for each location and movement type (Table 3) show the average impact was higher at the shank in all movements at both the fore and rear court. The IQR was also larger, again suggesting greater variation in impacts during match play. At the back sensor, the average impact was also higher in match play although the IQRs were more similar than for the shank. Whilst this might be expected due to the smaller values overall, it is still smaller when considered as fraction of the value such as for a variability statistic (i.e., IQR divided by median).

Table 1.
Average trial duration and movement locations .

		Trial Duration (s)	Movements Tagged	Forecourt Total	Rear Court Total	FCFH	FCBH	RCFH	RCATH
Match-Play	Mean	629.5	47.9	21.9	26.0	10.4	11.5	13.6	12.4
	SD	126.7	16.1	8.8	8.5	5.7	4.1	4.3	6.1
Multi-Feed	Mean	1008.6	151.2	80.6	70.6	45.7	34.9	36.3	34.3
	SD	213.4	32.2	18.0	15.6	12.2	10.1	8.6	8.6

Table 2
Comparison of peaks above 10 g thresholds

Threshold (g)	Shank						Back					
	Multi-Feed			Match-Play			Multi-Feed			Match-Play		
	Max	Median	IQR	Max	Median	IQR	Max	Median	IQR	Max	Median	IQR
100	1.2	0.1	0.2	6.0	0.6	1.7	0.0	0.0	0.0	0.0	0.0	0.0
90	1.2	0.1	0.3	2.5	0.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0
80	2.7	0.3	0.5	3.5	1.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0
70	6.1	0.7	1.2	6.8	2.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0
60	8.0	1.4	2.7	12.1	4.6	4.2	0.0	0.0	0.0	0.1	0.0	0.0
50	12.8	4.4	6.6	18.4	8.4	8.7	0.0	0.0	0.0	0.1	0.0	0.0
40	26.6	12.8	11.4	36.0	15.3	14.1	0.0	0.0	0.0	0.0	0.0	0.0
30	80.1	30.4	20.5	84.8	39.2	34.0	0.2	0.0	0.0	1.0	0.0	0.0
20	188.3	101.8	77.7	255.0	134.7	132.7	1.6	0.0	0.5	3.6	0.1	0.8
10	1099.8	586.7	152.1	1072.8	631.7	329.4	59.4	17.2	25.5	72.4	29.1	33.6

Table 3
Comparison of impacts for each location on court and movement tagged.

Location/Movement	Shank							Back						
	Multi-Feed			Match Play				Multi Feed			Match Play			
	Maximum	Median	IQR	Maximum	Median	IQR	P. value	Maximum	Median	IQR	Maximum	Median	IQR	P. value
Forecourt (g)	221.9	28.7	23.8	185.3	56.8	39.6	0.00*	15.8	6.1	3.1	30.5	7.8	3.9	0.00*
Rear Court (g)	133.8	23.9	29.8	199.8	29.8	36.2	0.00*	26.4	6.9	4.6	27.3	7.8	4.4	0.03*
Forecourt Forehand (g)	202.1	28.6	25.1	182.1	60.3	42.4	0.00*	15.8	6.1	3.0	30.5	7.8	3.8	0.00*
Forecourt Backhand (g)	221.9	28.9	22.1	185.3	53.4	39.3	0.00*	15.3	6.0	3.4	20.0	7.7	4.2	0.00*
Rear Court Forehand (g)	133.8	33.2	31.3	199.8	37.3	36.4	1.33	26.4	6.9	4.3	27.3	7.4	4.4	0.94
Rear Court ATH (g)	123.5	15.7	21.1	113.5	24.7	28.0	0.02*	23.6	6.9	4.9	23.1	8.2	4.3	7.25

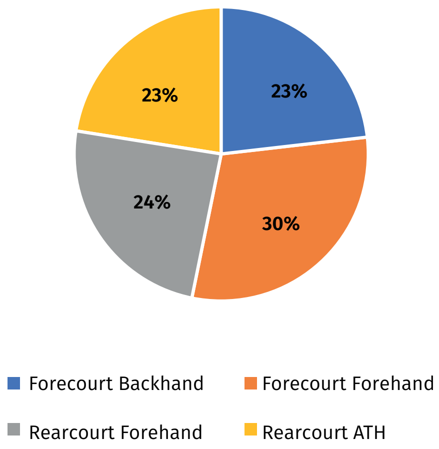

Figure 1a. Distribution of multi-feed movements.

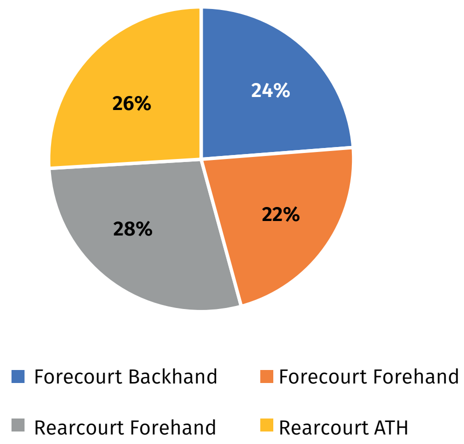

Figure 1b. Distribution of match-play movements.

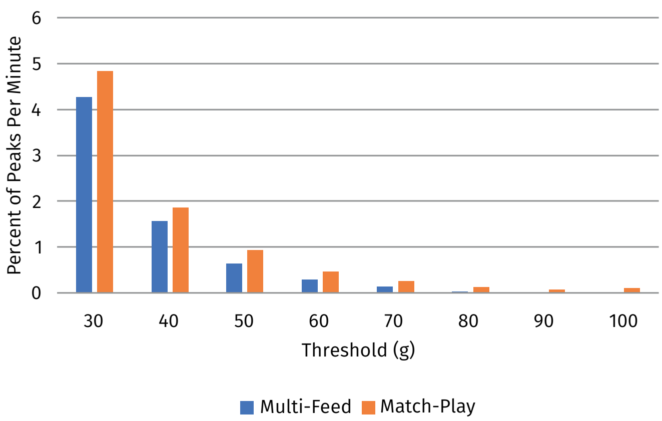

Figure 2a. Shank sensor peaks per minute (percent of movements).

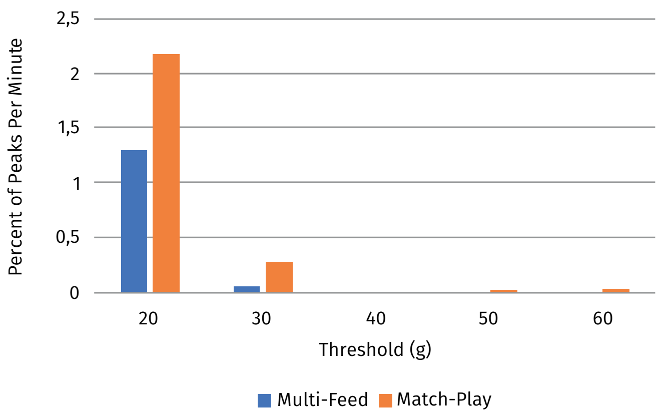

Figure 2b. Back sensor peaks per minute (percent of movements).

DISCUSSION

This study aimed to evaluate the mechanical load differences between predictable multifeed practice with low VSB and competitive match play with full VSB in badminton. Findings suggest that the mechanical load experienced in competitive match play is not simulated by practice activities that contain lower VSB, with match play trials producing significantly more mechanical load in the racket leg and lower back than multifeed trials. Due to the high prevalence of lower back and lower extremity injuries in badminton (Fatahi et al., 2022), findings support the need for increased VSB in badminton practice. In line with Smith et al. (2022), who reported biomechanical variations under different VSB scenarios, the mechanical load discrepancies found in the current study suggest badminton practice activities should contain high levels of VSB to prepare the body for the higher impacts experienced in match play.

The more visual stimuli to interpret, process and execute a response in badminton can produce reactive delays and movement inefficiency (Alder et al., 2014). When associated with previous research findings where full VSB was reported to produce a deeper lunge in badminton (Smith et al., 2022), current study results provide further evidence to suggest players initiate gross movements later with less anticipation and preparation, which increases the mechanical load on landing. The current study collected data from movements initiated at a central base position, and the greater requirement for the processing of spatial and temporal information (e.g., shuttlecock location and opponent body and arm position) in higher VSB scenarios seems to have a relationship with enhanced mechanical load. Importantly for injury prevention, the transfer of energy in the body and how it responds to physical loads is dependent on the nature and type of load, its rate, the frequency of load repetition and the magnitude of energy transfer (Bahr & Krosshaug, 2005). Therefore, practice activities that contain less energy transfer risk not preparing badminton players adequately for the mechanical loads experienced in competition.

When specific movements were isolated, mechanical load at the shank and back were significantly higher in match play trials in forehand and backhand forecourt lunges. The forecourt lunge in badminton has been reported to produce very high ground reaction forces (Hu et al., 2015), which is seen in the current study with noticeably higher mechanical loads at the shank. However, despite recording higher loads in all rear court movements, only the shank in RCATH was significantly higher. Therefore, low VSB practice activity with the forecourt lunge may be more detrimental to physical preparation than at the rear court, which is in line with previous badminton research that identifies high shearing forces experienced during single leg landing (Hu et al., 2022).

Currently there is no research that explores the longitudinal mechanical load differences between badminton practice and match play. Within other sports, load has been reported to be higher in practice than match play (e.g., Fox et al., 2018), however, mechanical load data is not commonly reported. Mechanical load during match play in the current study was found to be more varied and inconsistent with peaks occurring more often over time compared to multifeed trials. When equated to the amount of time spent in the practice environment compared to competition (Smith et al., 2020), the lower rate of impacts recorded during low VSB practice may have a significant influence on injury rate. Also, with a higher rate of peaks in match play, it could be assumed that mechanical load is experienced under differing fatigue levels (i.e., at the start and end of a rally).

Higher physiological loads have been found to decrease VSB efficiency in badminton (Alder et al., 2019), and when coupled with competitive match play that contains higher peaks and rates of mechanical load as indicated by the results in the current study, risk of injury is likely to increase due to enhanced overall load on the body. Therefore, physiological preparation activities should be centred around high VSB practice. Although limited in badminton, sport-specific training research (e.g., Hammami et al., 2018) and the study of perceptual information in representative learning designs (Pinder et al., 2011) have identified player physiological development to be more effective when athletes undertake activity with higher VSB, which is further supported by the results of the current study. Mental fatigue is also likely to have an impact on VSB (Miltner et al., 2004; Zeuwts et al., 2021) and increase mechanical load further. The current study increased threat and arousal in the match play scenario through monetary rewards, which will be difficult to replicate in standard practice activities and provides further evidence for the inappropriateness of low VSB practice activities.

Limitations and future research

The current study collected mechanical load at two prominent injury sites for badminton players, but further research is required to gather additional physiological load and fatigue measures in match play. Mechanical failure of biological tissues is poorly understood (Kalkhoven et al., 2021) and further research of load experienced by badminton players is required to design practice activities that are representative of competitive match play and decrease injury. Although reported as less prominent than the lower back as an injury site in the upper body, the shoulder is still an area for concern. The shoulder has complex mechanics that makes it a high-risk musculoskeletal system in overhead sports (Barnamehei et al., 2021) and future research could assess hitting action variations between different VSB situations to understand load differences. The current study was unable to detect the cause of the increased mechanical under high VSB conditions. The authors suggest that a processing lag contributes to a later initiation of movement, which could be studied by measurement of reaction time to external stimuli (e.g., opponent striking the shuttlecock) under different VSB conditions. Although this study simulated competitive match play to identify mechanical load peaks and rates, a more accurate measurement could be taken from tournament play with data collected over several sets and matches. Finally, average data for the population was reported, but it was visible within the data that loading between participants was likely to have varied. Therefore, future research should examine inter-individual differences to understand loading on an individual basis, along with the potential consequences for injury and training loads. Gender differences should also be assessed due to biomechanical differences (Hu et al., 2023), which was unachievable in the current study due to a low female sample.

CONCLUSION AND PRACTICAL IMPLICATIONS

The findings from this study suggest that badminton practice for high level players should contain activity high in VSB to prepare players for the high mechanical load of match play. Feeding drills should not be predictable. Unpredictability can be increased by the feeder having the freedom to hit the shuttlecock to other locations on the court as well as the target area for practice, which ensures the player can process the appropriate visual cues to initiate movement responses. The feeder should also hit the shuttlecock with an action that is representative of match play (i.e., whole body movement from base position to a returned shuttlecock and appropriate arm swing that replicates that seen in a competitive match). High VSB practice activity should continue throughout a practice session to mimic the high peak and rate of mechanical load found in match play. Coaches are advised that high VSB practice will increase mechanical load and adequate fatigue measurements should be undertaken to decrease injury within the practice environment.

FUNDING

This project has been carried out with the support of the Badminton World Federation (BWF).

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