Inter-and intra-individual differences in landing impacts during badminton match-play versus a feeding drill

Diferencias interindividuales e intraindividuales en los impactos al aterrizar durante un partido de bádminton frente a un ejercicio de alimentación

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Abstract

It is not understood the extent to which individuals experience impacts in badminton, and how this might relate to performance and injury risk. Little data are available on landing during match-play due to the limitations on collecting such data. This study aimed to capture acceleration data for badminton athletes in order to quantify individual differences. 19 athletes performed MF (multi-feed) drills and were paired to play matches. Each wore an accelerometer on their right lower tibia. Players were seen to have different patterns in the distribution of their impacts and hence "lighter" and "heavier" landers were identified. Typically, these were similar players across shot types, but not always (r2 = 0.7326 and P < 0.001). Those who won their matches encountered higher accelerations in all trial and shot types (though not all P. values were significant). Whilst both winners and losers encountered higher accelerations in match play (P < 0.001), the percentage increase was lower for winners (30%) than losers (42%). Results show that badminton players experience landings on an individual level. Better players experience higher g impacts more often, particularly in the training drill observed, which might indicate better efficiency of movement around the court or greater effort in training.

Keywords: *Racket sport, accelerometer, training versus match-play, winners versus losers.*

Resumen

No se conoce hasta qué punto los individuos experimentan impactos en bádminton y cómo esto podría relacionarse con el rendimiento y el riesgo de lesión. Hay poca información disponible sobre el aterrizaje durante un partido debido a las limitaciones que hay para recolectar los datos. El objetivo de este estudio fue capturar los datos de aceleración en atletas de bádminton con el fin de cuantificar las diferencias individuales. 19 atletas realizaron ejercicios de alimentación múltiple y fueron emparejados para jugar partidos. Cada uno usó un acelerómetro en la parte inferior de tibia derecha. Los jugadores tuvieron diversos patrones en la distribución de los impactos y, por tanto, se identificaron jugadores que aterrizaban más ligeramente y más fuertemente. Por lo general, los jugadores eran similares en todos los tipos de golpes, pero no siempre (r2 = 0.7326 y P < 0.001). Aquellos que ganaron los partidos tuvieron mayores aceleraciones en todos los tipos de ejercicios de práctica y golpes (aunque no todos los valores P. fueron significativos). Aunque tanto los ganadores como los perdedores tuvieron mayores aceleraciones en el partido (P < 0.001), el aumento en el porcentaje fue menor para los ganadores (30%) que para los perdedores (42%). Los resultados demuestran que los jugadores de bádminton experimentan aterrizajes a un nivel individual. Los mejores jugadores experimentan mayores impactos g más a menudo, particularmente en el ejercicio de práctica observado, lo cual puede indicar una mejor eficiencia en el movimiento alrededor de la cancha o mayor esfuerzo durante el entrenamiento.

Palabras clave: *Deporte de raqueta, acelerómetro, entrenamiento versus partido, ganadores versus perdedores.*

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INTRODUCTION

Badminton is played across some 194 countries by ~300 million people worldwide (BWF, 2019). It is a racket sport characterised by short bursts of fast play featuring jumps, lunges, overhead shots and multi-directional movement (Phomsoupha & Laffaye, 2015). As such, the ability to move with speed and agility offers players a competitive advantage (e.g. Cronin et al., 2003) however, with fast movements comes high loads and risk of injury. Injury rates for badminton are around 0.9 to 5.1 injuries per 1000 hours of playing time (Miyake et al., 2016). The consequence of such injury rates means the requirement of covering costs of medical treatment for immediate care and rehabilitation, as well as time spent recovering. Fahlström et al. (1998) considered that badminton accounts for around 1.2% of all sports injuries with an average 42 days sick leave for injuries that required emergency treatment in hospital.

Badminton injuries predominantly occur in the lower limb, which account for up to 83-92% of badminton injuries (Fahlström et al., 1998; Krøner et al., 1990) although overuse injuries are more common than acute ones (Ogiuchi et al. 1998 cited in Pardiwala, 2020). With this in mind, care should be taken when attempting to understand badminton injury epidemiology as incidence rates are often sourced from hospital admissions, which may not include a high proportion of certain injury types, and the focus might potentially become centred on more severe, acute injuries. With this in mind, ankle sprains, knee sprains, patella tendinopathy, anterior cruciate ligament injury and stress fractures are all cited as common lower limb injuries in badminton (Kaldau et al., 2021; Milon, 2017; Sandheera, 2019).

The mechanisms causing these injuries tend to be linked to jumping/ landing, lunging and changing direction which demand the production and absorption of high forces and accelerations (e.g., Milon, 2017; Robinson & O'Donoghue, 2008). Kimura et al. (2010) found that single-leg landings following backward step and overhead stroke was a significant cause of ACL injury on the knee opposite the racket side. The other main mechanism identified was from 'plant-and-cut during short steps' which injured the knee of the racket side. Guermont et al. (2021) specifically noted the lunge to be the footwork with the highest associated injury risk and accounted for 32% of lower limb injuries in elite players. Hong et al. (2013) noted that the direction of lunge influences peak impact force with the left-forward lunge generating significantly higher vertical force. Yu et al. (2021) further reinforced this linking left-side lunges to higher patellofemoral joint loads.

A question therefore exists as to when these badminton injuries occur. Phomsoupha and Laffaye (2020) recognised a higher rate of injuries in September which coincides with a greater proportion of scheduled tournaments. Indeed, injury rates in competition (11.6 injuries/ 1000 hrs playing) are higher than in training sessions (2.8 injuries/ 1000 hrs playing), and tend to occur more in the first third of play (Guermont et al., 2021). The reason for this may be linked to the loads that players experience when playing badminton matches being higher than those they experience during training (Smith et al., IN REVIEW). This therefore supports that the intensity of training, and its ability to prepare players for match situations, is crucial not only for skill related factors but also fitness and injury prevention.

High forces are a requirement for fast, explosive movements. This is a demonstration of Newton's second law of motion, explained by the formula, force is equal to mass multiplied by acceleration ($F = ma$). For example, Young et al. (1995) noted a series of strength-based predictors of sprint-start performance, the best of which was peak force relative to body weight. Interestingly, Cronin and Hansen (2005) observed correlations between selected leg strength measures and speed to be not significant. It is suggested therefore that producing high peak force rather than strength alone may be beneficial for the dynamic lunges, landings and changes of direction involved in badminton.

When the factors above are combined with individual differences related to BMI, anthropometry, strength and mobility, it is easy to see why not all players might experience the same accelerations and are not at the same risk of injury (Adae et al., 2017; Phomsoupha and Laffaye, 2020). Studies assessing impact kinetics have tended to use force plates which means it unlikely that data can be captured during match-play (e.g., Lam et al., 2018). It is therefore useful to understand how loads change on an individual basis between shot types, between match-play and training and according to player level (winners vs losers). The aim of this study was to assess inter-individual and intra-individual differences in accelerations recorded during match-play and training in order to provide insight to the extent to which different players expose themselves to contrasting loading conditions.

MATERIALS AND METHODS

The methods for this study have been previously presented in Smith et al., IN REVIEW). 19 high level badminton players (age 20.6 ± 6 years, stature 1.74 ± 0.11 m, mass 70.3 ± 13.3 kg, playing experience 10.7 ± 6.8 years) volunteered to perform a series of MF (multi-feed) drills (Smith et al., 2022), with the shot location and timing dictated by the coach. Athletes were then paired up at similar levels and played a match (MP, match-play condition) where a monetary prize (voucher) was given to the winner as incentive.

For each activity, athletes wore a Vicon Blue Trident IMU (inertial measurement unit) (Vicon Motion Systems Ltd, Oxford, UK) securely fastened to their lower shin on their lead leg. Tri-axial acceleration data were collected at 1600 Hz and all activities were also filmed using an Olympus Tough TG-5 camera (Olympus

Corporation, Tokyo, Japan) recording at 60 Hz. The video data allowed all shots of interest to be tagged using Dartfish (v10, Dartfish, Fribourg, Switzerland) (front court forehand, front court backhand, rear court forehand, rear court ATH (around the head)). Sensor and video data were synchronised based on the landing of a vertical jump performed at the beginning of each trial using Matlab (v9.13, MathWorks, Natick, MA, USA).

A window of 0.0167 s (the time for one frame of video) was created in the data around the time of each tagged event and the highest resultant acceleration was recorded. Acceleration data were resolved, converted to '*g*' and 1*g* was removed from each measurement to account for gravity.

Data were examined according to distribution of acceleration peaks observed by peaks above thresholds specified at every 10*g* up to 100*g*. Furthermore, the median peaks were used to help understand the distribution, and players were ranked accordingly where the player with the lowest rank had the 'lightest' landings (lowest median), and the player with the highest rank had the heaviest landings (highest median). Data were not normally distributed so Spearman Rank correlations were used to assess relationships whilst Wilcoxon Rank tests were used to assess differences between conditions.

RESULTS

The majority of impacts recorded occurred at lower acceleration thresholds. Some example distributions of the data can be seen in Figure 1 which shows forecourt shots. The Figure demonstrates large differences in the distribution of impacts between individuals. Taking the value of the median data point for each trial provides an indicator of the distribution of the data and hence the likelihood of the athlete being a 'heavier' or 'lighter' lander.

Typically, it appears that where players experienced higher *g* landings in MP, they also experienced high *g* landings in the MF trials. Figure 2 shows the average rank for players when ordered from 1-19 according to their average median impacts across all shots where a rank of 1 is the lowest median impact and 19 is the highest. Indeed, Spearman rank correlation provides an r-squared value of 0.7326 and P < 0.001. However, the large standard deviation bars suggest that these ranks are not consistent across all shot types.

Taking the four 'lightest' landers (those with the lowest mean rank across shots during MP), it can be further seen that none of them were in the lightest landers for all four shot types (Figure 3a). Also, when viewing the same four players during MF trials, their ranks were not always similar than during MP. For example, player 9 had ranks six and eight places higher for fore-court backhand and fore-court forehand respectively, but four places lower for rear-court forehand.

The four 'heaviest' landers (those with the highest mean rank across shots) show similar characteristic patterns to the lightest landers. Their ranks are still high whether in the MP or MF condition but there are large differences between shots for each player (Figures 3c and 3d).

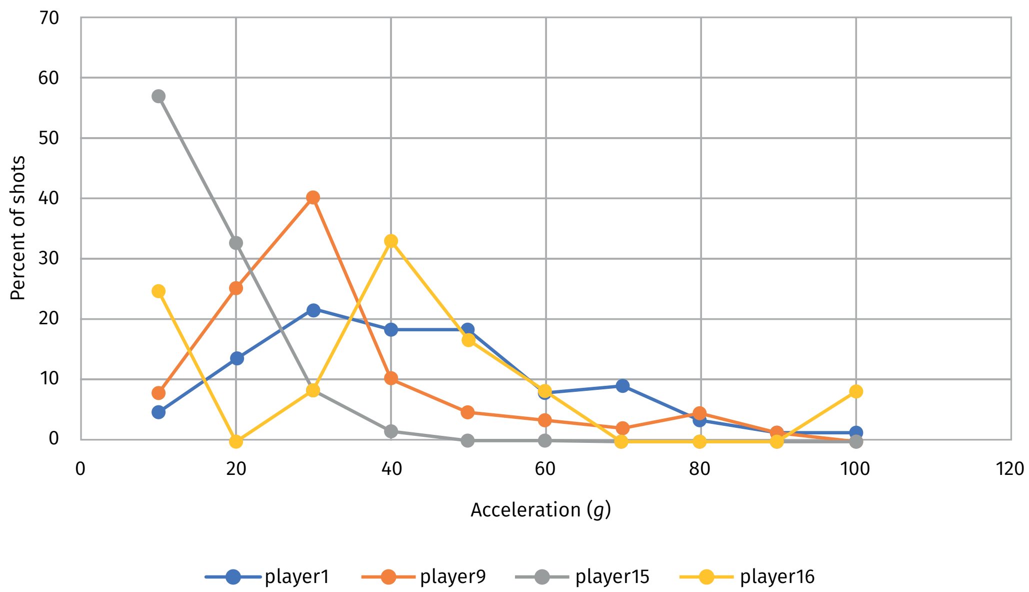

Figure 1. Example distributions of impact data during trials. This is from all fore-court shots during MF (multi-feed) trials for participants 1, 9, 15 and 16.

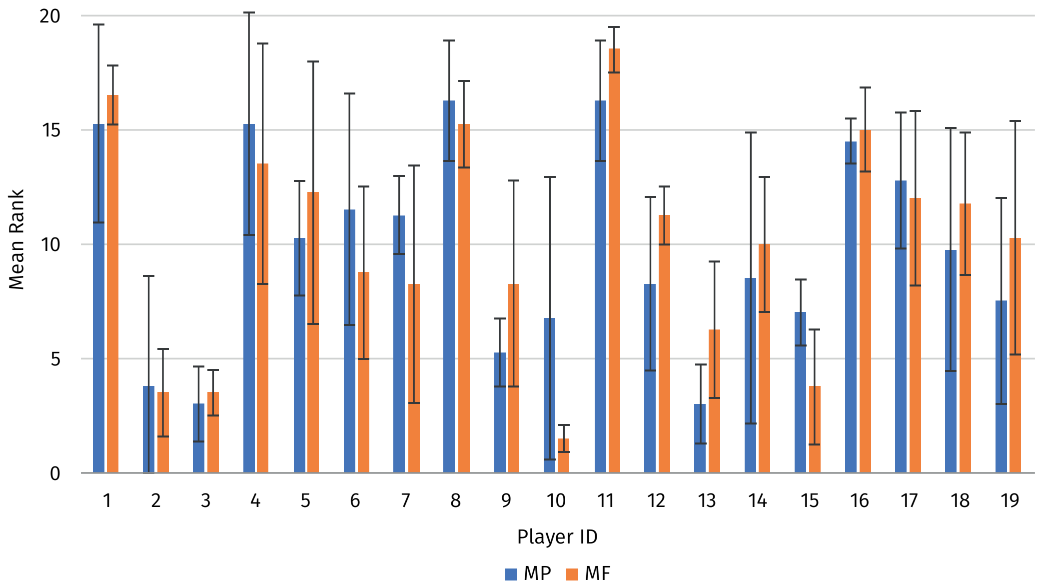

Figure 2. Player's mean rank according to median impact across all shots.

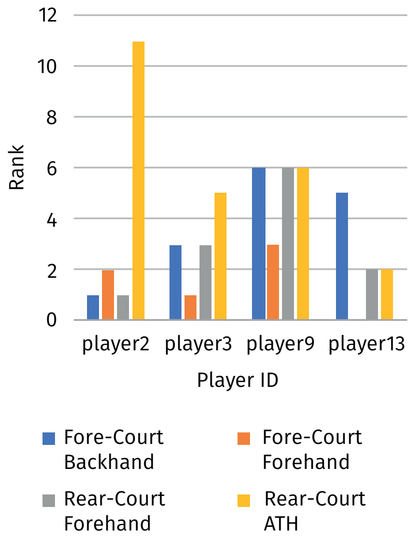

Figure 3a. The lightest landers in MP trials

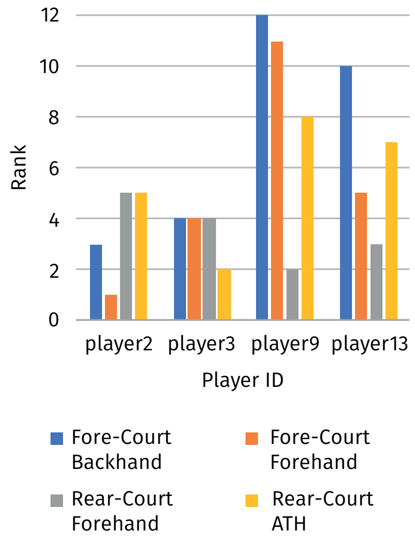

Figure 3b. The lightest landers from MP trials in the MF condition

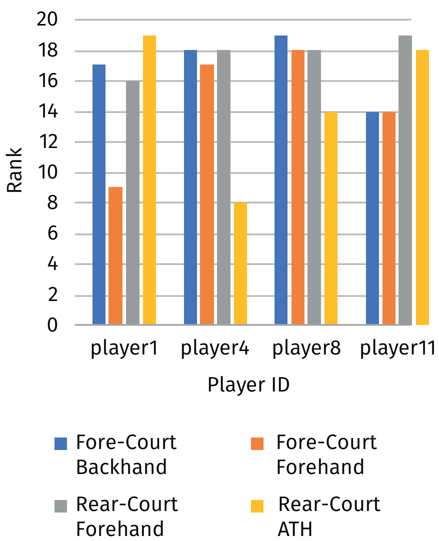

Figure 3c. The heaviest landers in MP trials

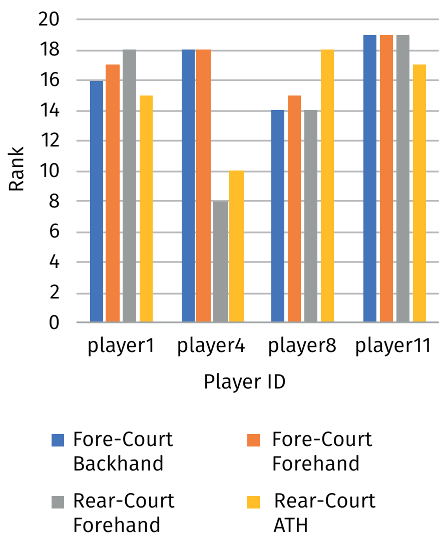

Figure 3d. The heaviest landers in MP trials in the MF condition

Finally, players were grouped by those who won their matches against those who lost. Of the example athletes given above for the four lightest landers, players 2 and 3 lost their matches but 9 and 13 won. Whereas for the four heaviest landers, all four won their matches. Overall, there were no significant differences in descriptive characteristics between winners and losers. However, comparison of means showed winners slightly younger (18.1 ± 2.6 vs 23.2 ± 7.7 years), with less experience (8 ± 2.8 vs 13.1 ± 8.9 years), shorter (1.72 ± 0.07 vs 1.77 ± 0.09 m), and lighter (69.0 ± 10.6 kg vs 73.3 ± 15.6 kg). Despite this, winners tended to record higher accelerations overall. Table 1 shows the ranks for winners and losers based on the size of accelerations recorded. For every shot type, the average acceleration was higher for winners in both MP and MF trials, although for MP this was only statistically significant for forecourt backhand shots ($p=0.011$, ES = -0.13) when grouped. During MF trials, the difference between winners and losers was significant for all shot types ($p<0.001$, ES = -0.19 - -0.3). Whilst these differences exist between groups, the increase in load from MF to MP for each is similar. When comparing, the difference in accelerations between groups between MF and MP (Figure 4), the average difference is 3.5 *g* in the rear court and 0 *g* in the forecourt although the largest difference was 9.6 *g* for forecourt forehand. However, when viewing the differences as a percentage of MP levels, winners experienced 70 % in MF compared to losers whose impacts were 58 % of those seen in MP. This difference is mainly due to large differences in forecourt shots where winners and losers experienced 55 % and 47 % of MP levels compared to 84 % and 68 % in the rear court shots respectively.

Table 1.
Average player rankings based on acceleration during landings.

Shot	Winners				Losers			
	MP		MF		MP		MF	
Rear-Court	11.4	± 4.9	12.6	± 5.5	9.4	± 6.1	7.8	± 5.2
Fore-Court	11.0	± 5.7	11.4	± 6.1	9.2	± 6.0	8.1	± 5.1
Fore-Court Backhand	11.7	± 5.5	11.9	± 5.6	8.3	± 5.9	7.6	± 5.1
Fore-Court Forehand	11.0	± 6.2	11.7	± 5.9	9.2	± 5.5	8.1	± 5.4
Rear-Court Forehand	11.3	± 5.9	11.3	± 6.4	8.6	± 5.7	8.6	± 5.0
Rear-Court ATH	11.4	± 5.9	12.2	± 5.3	9.6	± 4.9	8.6	± 5.4

MP = Match-play, MF = Multi-feed drill

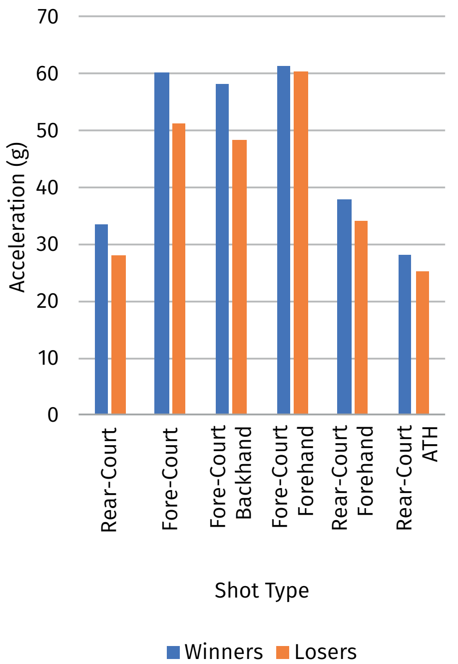

Figure 4a. Comparison of median accelerations during shots between winners and losers during MP (match play).

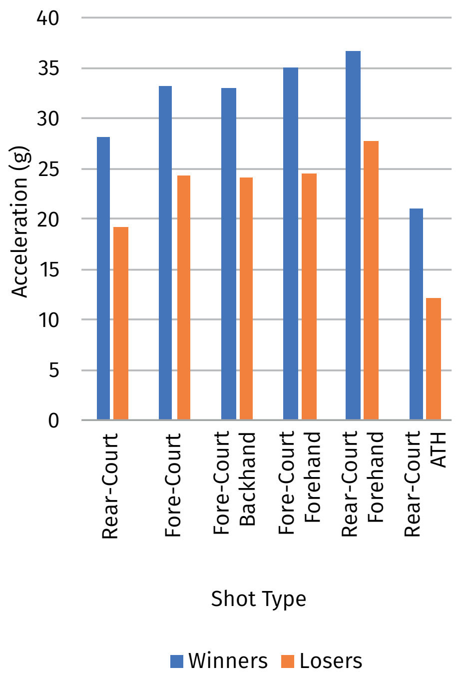

Figure 4b. Comparison of median accelerations during shots between winners and losers during MF (multi-feed) trials.

DISCUSSION

The aim of the study was to investigate intra-individual and group (winners vs losers) differences in acceleration data recorded during specified badminton moves. The data presented supports previous observations that larger impacts are seen during MP than MF trials (Smith et al., IN REVIEW). When the data were broken down into individual participants, it was largely seen that some players tended to be 'heavier' landers than others, whilst correlation exists, it was not necessarily consistent across shots. This suggests a level of difference in movement ability, strategy, or technique between players. This study therefore provides initial insight into the intra-individual differences that exist between badminton players.

It is particularly interesting that players who won their matches tended to exhibit higher accelerations than their opponents. It is therefore useful to consider why this might be an advantage and if these players are putting themselves at a greater risk of injury. Mechanically, higher accelerations should mean faster completion of movements such as landings and changes of direction although a high peak doesn't necessarily mean overall faster movement. However, it is peak forces which often best predict performance in explosive activities (Cronin and Hansen, 2005; Young et el., 1995). For example, Cronin et al. (2003) specifically noted that their best predictor of lunge performance was the ability to "produce peak force earlier in the concentric phase" on a supine squat. Lam et al. (2018) also observed that shorter foot contact time in the lunge coincided with higher peak horizontal forces whilst in fencing, Guan et al. (2018) observed that elite fencers produced a higher peak horizontal force which contributed to a higher velocity of the centre of mass.

The results for winners and losers are also interesting in light that there were no significant differences in group descriptive characteristics. If anything, it might be expected that the slightly higher stature and mass of the losers' group might result in larger impacts. However, as accelerations were measured rather than force, the lighter, shorter group might therefore be expected to be more agile and in turn, produce the higher numbers.

The differences between acceleration data for winners and losers were most pronounced in the MF condition, although this is exaggerated by the scale of the plots. The differences though are highlighted when viewing them as a percentage of match levels, where winners were working at 70 % compared to losers whose impacts were only 58 %. It could be postulated that this indicates the winners are likely more dynamic or "trying harder" in training drills. This then could have potential advantages for overall physical preparation in the short and long-term. Whilst it has been noted that higher training loads can contribute to injuries/ risk, it is also likely that training 'smart' helps in conditioning and hence injury prevention (Gabbet, 2016). Given that the median acceleration in MF were often ~25 *g* less than in MP, it also seems likely that the injury risk in this specific drill is also lowered.

Court location has been seen to have an influence on injury risk in relation to some movement/ shot types (e.g. Kimura et al., 2010). In the present study, athletes appeared to experience accelerations during MF closer to those seen in game levels in the rear court, than the forecourt. Again, it should be considered that the training drill observed in this study is not a representation of all training drills. Nonetheless, knowing how training drills reflect match-play, including the loading mechanics, is something that coaches may wish to consider when attempting to balance training load vs injury risk.

Landing with higher accelerations might suggest a higher level of conditioning. These players may be able to withstand higher forces without injury and therefore be able to make more efficient movements around the court. It is a common misconception among coaches that reducing forces is a requirement in movements such as landings. Whilst this might be desirable, as a reduction in peak force might relate to a reduction in injury risk, it is by no means a requirement for fast movements. A reduction in peak force is characterised by movements such as greater flexion in the hip and knees. However, these movements take time and higher accelerations are likely to mean less loss of height or less time spent slowing of the centre of mass, and hence the overall movements are completed more quickly.

Fu et al. (2017) noted differences in lunging kinetics and kinematics between professional and amateur players and linked this to probable differences in conditioning and potential injury risk. Whilst Lam (2018) also noted unskilled athletes to have a larger knee flexion moment and larger peak horizontal ground reaction force, their overall peak GRF was less, associated to lower loading rate and longer contact time. Again, this points towards different conditioning and ability to lunge at speed in players of lower ability.

Herbaut et al. (2018) compared injuries between French and Chinese badminton players and in-particular noted higher rates of injury in French players. This could have been due to numerous factors, such as anthropometry, approach to training, playing technique, healthcare etc. Given the discussion here, it would be interesting to understand if this might also be related to the types of training undertaken, year of experience, equivalent loads encountered, and if this provides equivalent preparation.

LIMITATIONS

The study was reliant on the attachment of the IMU's being consistent across participants. Whilst every step was taken to ensure this, it is possible that factors such as variations in the connection to the underlying bone, or even choice of footwear (e.g. Bouché et al., 2010), could affect the results. However, if this were the case to a considerable extent, it might be expected that greater consistency would have been seen in the ranking data across the different shot types.

The use of IMU's is also convenient for collecting data in match-play due to being light and unobtrusive, however the inclusion of three-dimensional coordinate data would be useful linking movement kinematics and therefore comprehending how the accelerations seen are linked to the movements performed.

CONCLUSION AND PRACTICAL IMPLICATIONS

It has been shown that loading differences exist between players and that, even when athletes are paired up to play based on being similar levels, the winner is likely to be able to utilise higher loads in their game. Landing with higher accelerations might be an advantage for breaking, changing direction and recovery from the shot. Where players experience higher loads, they are likely to do this across different shots (although there is large variation). However, the impacts seen in training drills may not replicate those seen in match-play and this may even vary according to shot-type and court location within the drill. Badminton coaches should therefore aim to ensure that where training exercises aim to reflect match-play, attention should be paid to the variety and intensity of practice.

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REFERENCES

Adae, A., Ariel, N., & Cory, K. (2017). Body mass index as a predictor of injuries in athletics. *Current sports medicine reports, 17*(4), 256-262. https://doi.org/10.1249/JSR.0000000000000383

Badminton World Federation [BWF]. (2019). *About Badminton.* Badminton World Federation. https://corporate.bwfbadminton.com/about/about-badminton/

Bouché, R. T. (2010). Racquet Sports: Tennis, Badminton, Squash, Racquetball, and Handball. In M. B. Werd, & E. L. Knight (Eds.), *Athletic Footwear and Orthoses in Sports Medicine* (pp. 215-223). New York: Springer. https://doi.org/10.1007/978-0-387-76416-0_19

Høyer, P-H., & Lund, T. (2019). *BWF 2019 Annual Report*. Badminton World Federation.

Cronin, J., McNair, P. J., & Marshall, R. H. (2003). Lunge performance and its determinants. *Journal of Sports Sciences, 21*, 49-57. https://doi.org/10.1080/0264041031000070958

Cronin, J., & Hansen, K. T. (2005). Strength and power predictors of sports speed. *Journal of Strength and conditioning Research, 19*(2), 349-357. https://doi.org/10.1519/00124278-200505000-00019

Fahlström, M. Björnstig, U., & Lorentzon, R. (1998). Acute badminton injuries. *Scandinavian Journal of Medicine and Science in Sports, 8*, 145-148. https://doi.org/10.1111/j.1600-0838.1998.tb00184.x

Fu, L., Ren, F. & Baker, J.S. (2017). Comparison of Joint Loading in Badminton Lunging between Professional and Amateur Badminton Players. *Applied Bionics and Biomechanics, 2017,* 1-8. https://doi.org/10.1155/2017/3751202

Gabbet, T. (2016). The training - injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine, 50*, 273-280. https://doi.org/10.1136/bjsports-2015-095788

Guan, Y., Guo, L., Wu, N., Zhang, L., & Warburton, D.E.R. (2018). Biomechanical insights into the determinants of speed in the fencing lunge. *European Journal of Sports Science, 18*, 201-208. https://doi.org/10.1080/17461391.2017.1414886

Guermont, H., Le Van, P., Marcelli, C. Reboursière E., & Drigny J. (2021). Epidemiology of injuries in elite badminton players: A prospective study. Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine, 31(6), 473-475. https://doi.org/10.1097/JSM.0000000000000848

Herbaut, A., Delannoy, J., & Foissac, M. (2018). Injuries in French and Chinese regular badminton players. *Science & Sports, 33*(3), 145-151. https://doi.org/10.1016/j.scispo.2018.02.001

Hong, Y., Wang, S.J., Lam, W.K., & Cheung, J.T-M. (2013). Kinetics of badminton lunges in four directions. *Journal of Applied Biomechanics, 30*(1), 113-118. https://doi.org/10.1123/jab.2012-0151

Kaldau, N.C., Kerr, S., & McCaig, S. (2021). Training and injuries among world elite junior badminton players - Identifying the problems. *Asia Pacific Journal of Sports Medicne and Arthroscopy Rehabilitation Technology, 26,* 21-6. https://doi.org/10.1016/j.asmart.2021.07.003

Kimura, Y., Ishibashi, Y., Tsuda, E., Yamamoto, Y., Tsukada, H. & Toh, S. (2010). Mechanisms for anterior cruciate ligament injuries in badminton. *British Journal of Sports Medicine, 44*(15), 1124-1127. https://doi.org/10.1136/bjsm.2010.074153

Krøner, K., Schmidt, S. A., Nielsen, A. B., Yde, J., Jokobsen, B.W., Møller-Madsen, & Jensen, J. (1990). Badminton Injuries. *British Journal of Sports Medicine, 24*(2), 169-172. https://doi.org/10.1136/bjsm.24.3.169

Lam, W-K. Lee, K-K., Park, S-K., Ryue, J., Y, S-H. & Ryu, J. (2018). Understanding the impact loading characteristics of a badminton lunge among badminton players. *PLoS ONE, 13*(10), e0205800. https://doi.org/10.1371/journal.pone.0205800

Pardiwala, D. N. Subbiah, K., Rao, N., & Modi, R. (2020). Badminton Injuries in Elite Athletes: a review of epidemiology and biomechanics. *Indian Journal of Orthopaedics, 54*(3), 237-245. https://doi.org/10.1007/s43465-020-00054-1

Phomsoupha, M., & Laffaye, G. (2015). The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. *Sports Medicine, 45*(4), 473-495. https://doi.org/10.1007/s40279-014-0287-2

Phomsoupha, M., & Laffaye, G. (2020). Injuries in badminton: A review. *Science & Sports, 35*, 189-199. https://doi.org/10.1016/j.scispo.2020.01.002

Milon, G. A. (2017). Study Regarding the Types of Incidence of Lower Limb Injuries in Romanian Badminton Players. *Scientific Journal of Education, Sports, and Health, 18*(1), 212-218. https://doi.org/10.29081/gsjesh.2017.18.1.16

Miyake, E., Yatsunami, M., Kurabayashi, J., Teruya, K., Sekine Y,. Endo, T., Nishida, R., Takano, N., Sato, S., & Kyung, H. J. (2016). A prospective epidemiological study of injuries in Japanese national tournament-level badminton players from junior high school to university. *Asian Journal of Sports Medicine, 7*(1), e29637. https://doi.org/10.5812/asjsm.29637

Robinson, R., & O'Donoghue, P. (2008). A movement classification for the investigation of agility demands and injury risk in sport. *International Journal of Performance Analysis of Sport, 8*(1), 127-144. https://doi.org/10.1080/24748668.2008.11868428

Sandheera, V. V. (2019). Epidemiological Review of Badminton Related Injuries Among Competitive Badminton Players. *International Journal of Sports Science and Physical Education, 4*(3), 41-44. https://doi.org/10.11648/j.ijsspe.20190403.12

Smith, S. M., Tasker, E., Paine, E., Hughes, T. M., Heiden, C., & Baczala, O. (2022). Skill Acquisition and Development Issues with Predictable Badminton Feeding Routines. International *Journal of Physical Education, Fitness and Sports, 11*(1), 20-29. https://doi.org/10.34256/ijpefs2213

Young, W., McLean, B. & Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *The Journal of Sports Medicine and Physical Fitness, 35*, 13-19.

Yu, L., Mei, Q., Nur, I.M., Gu, Y. & Fernandez, J. (2021). An exploratory investigation of patellofemoral joint loadings during directional lunges in badminton. *Computers in Biology and Medicine, 132*, 104302. https://doi.org/10.1016/j.compbiomed.2021.104302