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Path analysis of physical and psychological determinants of *mawashi geri* performance in Kempo

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ABSTRACT

This study aimed to examine the direct and indirect effects of lower-limb explosive power, foot-eye coordination, and concentration on mawashi geri kicking performance among Kempo athletes. A quantitative causal-associative design was employed involving 22 male senior Kempo athletes selected through purposive sampling. Lower-limb explosive power, foot-eye coordination, concentration, and mawashi geri performance were assessed using standardized field tests. Data were analyzed using descriptive statistics, assumption testing, and path analysis with IBM SPSS Statistics 26. Lower-limb explosive power ($\beta = 0.460$, $p = 0.031$), foot-eye coordination ($\beta = 0.539$, $p = 0.010$), and concentration ($\beta = 0.555$, $p = 0.007$) significantly influenced mawashi geri performance. Collectively, these variables explained 48.5% of performance variance ($R^2 = 0.485$). Integrated physical and psychological training emphasizing explosive power, coordination, and concentration is essential for optimizing mawashi geri performance in competitive Kempo athletes.

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Introduction

Martial arts have become an important field of sport science because competitive performance is determined by the integration of physical, technical, tactical, and psychological components rather than by isolated physical abilities alone (Ansharudin et al., 2022; Doewes et al., 2025; Ramirez, 2023). In Kempo, the mawashi geri (roundhouse kick) is one of the primary offensive techniques used to generate scoring opportunities, requiring high levels of speed, accuracy, force production, and movement control. Successful execution of this technique depends not only on technical proficiency but also on the athlete's ability to integrate physical capacity with cognitive control during dynamic combat situations. Recent developments in combat sport research have therefore shifted from examining individual physical attributes toward understanding multidimensional factors that collectively influence technical performance (Cox, 2010; Semiun, 2020). Despite this development, empirical evidence explaining the determinants of mawashi geri performance in Kempo athletes remains limited, highlighting the need for further investigation to support evidence-based training strategies.

Among the physical factors, lower-limb explosive power and foot-eye coordination are considered fundamental prerequisites for effective kicking performance. Explosive power enables rapid force production through the hip, knee, and ankle joints, increasing kicking velocity and impact force, whereas foot-eye coordination facilitates the integration of visual information with lower-limb movement to improve temporal accuracy, movement precision, and neuromuscular efficiency during kick execution. Previous studies have

consistently demonstrated that lower-limb power contributes to kicking velocity and technical effectiveness, while perceptual-motor coordination enhances movement accuracy across striking combat sports, including karate and taekwondo (Gunawan et al., 2022; Nuryadin et al., 2023; Wati et al., 2024; Zivin et al., 2001). Although these findings provide a strong theoretical basis, their applicability to Kempo athletes, particularly in relation to mawashi geri performance, has not been comprehensively established.

Beyond physical capacity, psychological readiness, particularly concentration, is widely recognized as an essential determinant of technical performance in combat sports. Concentration enables athletes to maintain attentional focus on task-relevant stimuli while suppressing internal and external distractions, thereby improving movement timing, postural control, decision-making, and motor precision during complex kicking actions (Seputra et al., 2022). Previous studies have consistently reported positive associations between attentional control and motor performance; however, most investigations have examined concentration as an independent predictor rather than as part of an integrated performance model involving physical capacities (Mukai et al., 2025; Simanjuntak et al., 2022). Consequently, the interaction between physical attributes and concentration in determining mawashi geri performance remains insufficiently understood.

Although previous studies have demonstrated that lower-limb explosive power, coordination, and concentration are associated with technical performance, these variables have generally been examined separately or limited to direct relationships. Existing research in combat sports has predominantly focused on biomechanical characteristics, muscular strength, or physiological adaptations without simultaneously evaluating physical and psychological factors within a unified causal framework (Hashimoto et al., 2008; Nurtjahjaningsih et al., 2020). Moreover, empirical studies specifically investigating mawashi geri performance among Kempo athletes remain scarce, as most available evidence is derived from karate and taekwondo populations. In addition, limited attention has been given to the potential role of concentration in explaining how physical capacities contribute to technical kicking performance. These limitations indicate a clear research gap that warrants a more comprehensive analytical approach.

To address these limitations, the present study integrates lower-limb explosive power, foot-eye coordination, and concentration into a single path analysis model to estimate direct, indirect, and total effects on mawashi geri kicking performance. Compared with conventional correlation and regression approaches, path analysis provides a more comprehensive evaluation of the causal relationships among physical, psychological, and technical variables while allowing the potential mediating role of concentration to be examined (Matsumoto & Kimura, 1985; Nurkholis et al., 2023). The novelty of this study lies in the development of an integrated model that simultaneously examines physical and psychological determinants of mawashi geri performance among competitive Kempo athletes, a topic that has received limited empirical attention compared with karate and taekwondo (Ikeda et al., 2025; Uragami & Suzuki, 2017; Wilkerson, 1997). Therefore, this study aims to analyze the direct and indirect effects of lower-limb explosive power and foot-eye coordination on mawashi geri kicking performance through concentration, providing evidence to support more integrated training programs in competitive Kempo.

Method

This study employed a quantitative causal-associative design to examine the direct and indirect relationships among lower-limb explosive power, foot-eye coordination, concentration, and mawashi geri kicking performance in Kempo athletes. Path analysis was selected to simultaneously estimate direct, indirect, and total effects within a single causal model. Lower-limb explosive power (X_1) and foot-eye coordination (X_2) were specified as exogenous variables, concentration (X_3) as the mediating variable, and mawashi geri kicking performance (Y) as the endogenous variable. The study was conducted at the Kempo Dojo of Padang City, Indonesia. From a population of 68 registered athletes aged 10–22 years, 22 senior male athletes were selected through purposive sampling based on the following criteria: (1) active registered Kempo athletes, (2) senior male category, (3) regular participation in training, and (4) willingness to participate. Restricting the sample to senior male athletes minimized biological variability and improved the homogeneity of the proposed causal model.

Data were collected using four standardized field tests. Lower-limb explosive power was measured using the Vertical Jump Test, foot-eye coordination using the Soccer Wall Pass Test, concentration using the Grid Concentration Test (GCT), and mawashi geri performance using a standardized 10-second kicking test, with the best score from three trials recorded for analysis. All tests followed standardized administration procedures. Descriptive statistics were calculated prior to assumption testing, including the Shapiro–Wilk normality test, linearity test, and multicollinearity diagnostics (Tolerance > 0.10; VIF < 10). The hypothesized relationships were analyzed using path analysis in IBM SPSS Statistics 26 with a significance level of $p < 0.05$. Direct, indirect, and total effects were estimated to evaluate the mediating role of concentration.

Results and Discussions

This study investigated the direct and indirect effects of lower-limb explosive power, foot-eye coordination, and concentration on the mawashi geri kicking performance of Kempo athletes through path analysis. Prior to hypothesis testing, descriptive statistics and assumption tests were conducted to verify the suitability of the data for multivariate analysis. The findings demonstrated that all variables satisfied the assumptions of normality, linearity, and absence of multicollinearity, allowing the proposed path model to be tested. The results of the direct, indirect, and simultaneous effect analyses are presented in the following tables.

Table 1. Descriptive Statistics of the Study Variables

Variable	N	Min	Max	Mean	SD	Variance
Lower-limb explosive power	22	8.70	12.60	10.60	1.26	1.59
Foot-eye coordination	22	2	9	5.40	1.97	3.86
Concentration	22	8	19	12.00	3.22	10.38
Mawashi geri kicking performance	22	12	19	15.40	1.65	2.73

Table 1 presents the descriptive statistics of the study variables collected from 22 Kempo athletes. Lower-limb explosive power showed a mean score of 10.60 ± 1.26, while foot-eye coordination averaged 5.40 ± 1.97. The concentration variable demonstrated a mean score of 12.00 ± 3.22, indicating greater variability than the physical variables. Mawashi geri kicking performance recorded the highest mean (15.40 ± 1.65), suggesting that most athletes demonstrated relatively good kicking performance. Overall, the descriptive statistics indicate adequate variability across all variables, supporting subsequent inferential analyses.

Table 2. Results of Assumption Testing

Test	Variable/Relationship	Statistic	Result
Normality	Lower-limb explosive power	p = 0.174	Normal
	Foot-eye coordination	p = 0.365	Normal
	Concentration	p = 0.082	Normal
	Mawashi geri performance	p = 0.226	Normal
Linearity	X_1 to X_3	p = 0.928	Linear
	X_2 to X_3	p = 0.633	Linear
	X_1 to Y	p = 0.888	Linear
	X_2 to Y	p = 0.342	Linear
	X_3 to Y	p = 0.956	Linear
Multicollinearity	Lower-limb explosive power	VIF = 1.236	No multicollinearity
	Foot-eye coordination	VIF = 1.161	No multicollinearity
	Concentration	VIF = 1.285	No multicollinearity

The assumption tests confirmed that the dataset fulfilled the requirements for path analysis. All variables exhibited normal distributions, with Shapiro–Wilk significance values exceeding the 0.05 threshold. Likewise, every predictor–outcome relationship satisfied the linearity assumption, as evidenced by non-significant deviation-from-linearity values (all $p > 0.05$). Furthermore, multicollinearity diagnostics revealed tolerance values above 0.10 and VIF values well below 10, indicating that no serious multicollinearity existed among the independent variables. These findings confirm that the proposed path model was statistically appropriate for further analysis.

Table 3. Direct Effects of Lower-Limb Explosive Power and Foot-Eye Coordination on Concentration (Substructure I)

Path	β	R	R^2	t	p	Decision
Explosive power to Concentration	0.410	0.410	0.168	2.009	0.058	Not significant
Foot-eye coordination to Concentration	0.338	0.338	0.115	1.609	0.123	Not significant

The first substructure examined whether lower-limb explosive power and foot-eye coordination predicted athletes' concentration. Although both predictors demonstrated positive standardized coefficients, neither relationship reached statistical significance. Lower-limb explosive power showed a moderate positive association with concentration ($\beta = 0.410$, $p = 0.058$), while foot-eye coordination demonstrated a weaker positive relationship ($\beta = 0.338$, $p = 0.123$). These findings indicate that improvements in these physical attributes alone were insufficient to produce significant changes in concentration among the participating athletes.

Table 4. Direct Effects on Mawashi Geri Kicking Performance (Substructure II)

Path	β	R	R^2	t	p	Decision
Explosive power to Mawashi geri	0.460	0.460	0.211	2.316	0.031	Significant
Foot-eye coordination to Mawashi geri	0.539	0.539	0.290	2.860	0.010	Significant
Concentration to Mawashi geri	0.555	0.555	0.308	2.981	0.007	Significant

Table 4 demonstrates that all three predictors exerted statistically significant positive effects on mawashi geri performance. Concentration emerged as the strongest predictor (β = 0.555, p = 0.007), followed by foot-eye coordination (β = 0.539, p = 0.010) and lower-limb explosive power (β = 0.460, p = 0.031). These findings indicate that athletes with better concentration, superior coordination, and greater explosive power tend to exhibit higher-quality mawashi geri kicking performance. Among these variables, concentration contributed the greatest proportion of explained variance (R^2 = 0.308).

Table 5. Direct, Indirect, and Total Effects

Path	Direct Effect	Indirect Effect	Total Effect
Explosive power to Mawashi geri	0.460	0.228	0.688
Foot-eye coordination to Mawashi geri	0.539	0.188	0.727
Concentration to Mawashi geri	0.555	–	0.555

The mediation analysis showed that concentration partially transmitted the effects of the physical variables on kicking performance. Lower-limb explosive power produced an indirect effect of 0.228, resulting in a total effect of 0.688, whereas foot-eye coordination generated an indirect effect of 0.188 and the largest overall effect (0.727). Concentration acted solely as a direct predictor because it was specified as the mediating variable within the model. These results suggest that concentration enhances the contribution of physical abilities to successful mawashi geri execution, particularly for athletes with superior coordination.

Table 6. Simultaneous Effects of All Predictors on Mawashi Geri Performance

Model	R	R^2	F	p
Explosive power + Foot-eye coordination + Concentration to Mawashi geri	0.697	0.485	5.653	0.007

The simultaneous regression analysis demonstrated that the combined model was statistically significant (F = 5.653, p = 0.007). The multiple correlation coefficient (R = 0.697) indicated a strong relationship between the predictor variables and mawashi geri performance. Furthermore, the model explained 48.5% of the variance in kicking performance (R^2 = 0.485), while the remaining 51.5% was attributable to variables not included in the present study. These findings suggest that lower-limb explosive power, foot-eye coordination, and concentration collectively represent important determinants of mawashi geri performance among Kempo athletes.

The present study demonstrated that lower-limb explosive power significantly influenced mawashi geri kicking performance (β = 0.460, p = 0.031), indicating that athletes with greater explosive capability tended to perform more effective kicks. Although explosive power showed a positive association with concentration (β = 0.410), this relationship did not reach statistical significance (p = 0.058), suggesting that muscular power primarily contributes directly to kicking execution rather than indirectly through attentional processes. Biomechanically, explosive force generated by the hip, knee, and ankle extensors enables greater acceleration of the kicking limb, producing higher impact velocity and more effective force transfer during the execution of the mawashi geri technique. These findings support the principle that explosive muscular performance is a fundamental determinant of high-speed kicking movements in martial arts and is consistent with previous studies reporting that lower-limb power substantially enhances kicking velocity, impact force, and technical effectiveness (Fauzan et al., 2023; Lupu et al., 2026; Pfeiffer et al., 2006).

Foot-eye coordination emerged as another important determinant of performance, demonstrating a significant direct effect on mawashi geri performance (β = 0.539, p = 0.010), which was stronger than the contribution of lower-limb explosive power. However, its direct relationship with concentration remained statistically non-significant (β = 0.338, p = 0.123). These findings indicate that coordination contributes primarily through improving movement precision, temporal synchronization, and neuromuscular control rather than enhancing cognitive concentration. Effective execution of the mawashi geri technique requires accurate visual perception, rapid motor planning, and precise synchronization between visual input and lower-limb movement. Athletes possessing superior coordination are therefore able to execute kicks with greater accuracy and consistency during dynamic combat situations. These findings agree with previous evidence emphasizing that perceptual-motor coordination is a critical component of technical performance in striking combat sports, particularly during high-speed kicking actions requiring continuous visual feedback (Becker & Kuttig, 1974; Matsumoto et al., 1988; Winarti & Salahuddin, 2024).

Among all predictors, concentration demonstrated the strongest direct influence on mawashi geri performance ($\beta = 0.555$, $R^2 = 0.308$, $p = 0.007$), explaining approximately 30.8% of the variance in kicking ability. This result indicates that psychological readiness contributes even more strongly than the investigated physical variables to successful kicking performance. Athletes capable of maintaining sustained attentional focus are more likely to execute appropriate movement timing, preserve postural stability, and accurately direct kicking trajectories toward the intended target despite environmental distractions. Interestingly, although neither explosive power nor coordination significantly predicted concentration, concentration itself substantially enhanced kicking performance once incorporated into the structural model. This finding reinforces contemporary sport psychology theories suggesting that attentional control functions as an independent performance determinant that directly influences motor execution quality rather than merely mediating physical capacities (Grigore et al., 2011; Manihuruk et al., 2022; Narabayashi, 1974).

The mediation analysis further revealed that concentration partially strengthened the influence of the physical variables on kicking performance. Lower-limb explosive power produced an indirect effect of 0.228, resulting in a total effect of 0.688, whereas foot-eye coordination generated an indirect effect of 0.188 and the largest total effect (0.727). Although the indirect pathways were relatively modest because the physical variables did not significantly predict concentration, these findings indicate that concentration still amplifies the contribution of physical abilities to overall kicking performance. From a practical coaching perspective, technical development should therefore integrate physical conditioning with psychological skills training rather than treating these components independently. Programs combining plyometric exercises, coordination drills, and structured concentration training may produce greater improvements in mawashi geri performance than interventions focusing exclusively on physical conditioning. Similar multidimensional approaches have previously been recommended for optimizing technical performance in elite combat sport athletes (Gunawan et al., 2025; Huffman, 2013; Suzuki et al., 2011; Umegaki, 1974).

The simultaneous regression analysis demonstrated that lower-limb explosive power, foot-eye coordination, and concentration collectively explained 48.5% of the variance in mawashi geri performance ($R = 0.697$, $R^2 = 0.485$, $F = 5.653$, $p = 0.007$). This finding indicates that nearly half of kicking performance can be explained by the integrated contribution of these three variables, while the remaining 51.5% is likely attributable to additional determinants not examined in the present study, such as lower-limb flexibility, reaction time, dynamic balance, technical experience, tactical decision-making, anthropometric characteristics, fatigue resistance, and psychological factors including competitive anxiety and self-confidence. Consequently, mawashi geri performance should be viewed as a multidimensional motor skill resulting from the interaction of physical, neuromuscular, technical, and psychological components (Adachi, 1974; Feng et al., 2025; Shinagawa et al., 1997; Soga, 2017). Future research should therefore adopt broader structural models incorporating biomechanical, physiological, and psychological variables simultaneously to provide a more comprehensive explanation of technical performance in Kempo and other striking martial arts.

Conclusions

This study concludes that lower-limb explosive power, foot-eye coordination, and concentration are significant determinants of mawashi geri kicking performance among Kempo athletes. Lower-limb explosive power and foot-eye coordination each exerted significant direct effects on kicking performance, while concentration emerged as the strongest direct predictor. Although lower-limb explosive power and foot-eye coordination did not significantly influence concentration directly, concentration partially mediated their relationships with mawashi geri performance, resulting in greater total effects. Furthermore, the three variables collectively explained 48.5% of the variance in kicking performance, indicating that both physical and psychological factors play complementary roles in successful technical execution. These findings highlight the importance of integrating explosive power development, coordination training, and concentration enhancement within a comprehensive training program to optimize mawashi geri performance in competitive Kempo athletes.

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